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ROYAL AIRCRAFT ESTABLISHMENT

(FARNBOROUGH)

TECHNICAL NOTE No: MECH. ENG. 297

CONTINUOUS ROD WARHEAD LETHALITY TRIALS AGAINST B.29 AIRCRAFT WINGS

(3/16, ¼ AND 5/16 inch SQUARE-SECTION RODS)

by

R.G.E.MALLIN, A.F.R.Ae.S., G.I. Mech.E,

JULY, 1959

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RAE Ref: ME/B3/9072/RGEM

SUMMARY

This Note records the results of nine static detonations of 3/16, ¼ and 5/16 inch square-section continuous rod warheads against Boeing B.29 aircraft wings, eight of which were loaded to simulate flight conditions at the attack station. The results show that when attacking the inboard lower surface of the wing none of the rods is capable of producing structural kills of the target, even from the most favourable directions of rod approach. Against the wing outboard of the engines, however, all three types of warhead are able to cause complete failure of the wing structure, resulting in a Cat. 'K' kill of the target.

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1 INTRODUCTION

1.1 Previous trials[1,2] against stationary, unloaded, targets have shown that wing structures having concentrated load-carrying members, such as those of the Boeing B29 and as assumed for the Russian Type 39 'Badger', are difficult to defeat by continuous rod attack.

1.2 Limited trials[3] have been made in the U.S.A. in which B29 wings, loaded to reproduce level flight stresses in the structure at the point of attack, were defeated by 3/16 and ¼ inch square-section continuous rods. It was decided to make similar, complementary, trials in this country, from which it was hoped that more data would be obtained on the effectiveness of continuous rods, of various cross-sectional dimensions, against heavy aircraft structures.

1.3 This Note records the results of a series of firings made at the P. & E.E. (Shoeburyness) between April 1958 and January 1959.

2 OBJECTS OF THE TRIALS

2.1 The main objects were:-

(a) To determine the influence of flight loads on the effectiveness of continuous rods when attacking aircraft wings.

(b) To compare the effectiveness of 3/16, ¼ and 5/16 inch square-section continuous rods when attacking various sections of a loaded wing having heavy spar booms.

(c) To correlate rod damage with direction of rod approach.

2.2 Secondary objects of the trials were:-

(a) To accumulate data on continuous rod effectiveness for use in G.W. warhead lethality assessments.

(b) To determine the magnitude of blast effects from typical continuous rod warheads at representative target distances.

3 TRIAL PROGRAMME

3.1 A total of nine firings was made against structurally complete B29 aircraft wings, one of the wings being unloaded when attacked, seven loaded to 1W (level flight cruise condition) and one loaded to 1.5W. Of these, six attacked the inner portion of the wing, two the mid-section and one the outer wing.

3.2 Although, in general, a missile having a continuous rod warhead is equally likely to strike the target from above as from below, it was decided to attack the B29 wings from below, because the lower surfaces incorporate the heavy spar booms which the continuous rod must be expected to meet, and defeat, in service.

3.3 In eight of the firings, the warhead was detonated in a typical attack position i.e. 45° below ahead and 45° off ahead, relative to the selected station, such that the rod struck the lower surface of the wing at approximately 45° to the normal, producing a chordwise cut. In the remaining firing, the warhead was positioned so that the rods struck at normal from below and produced a chordwise cut, a condition thought likely to produce maximum damage effect.

3.4 The following data were recorded during some or all of the firings:-

(a) Wing tip deflections during loading and unloading of the wings.

(b) Wing tip deflections before, during and after warhead detonation.

(c) Blast measurements around the warhead.

(d) Mean rod velocities between warhead and target.

3.5 A summary of the firings and of the trial conditions, is given in Table 1A.

4 WARHEADS

4.1 Experimental models of Blue Jay and Red Dean warheads were used to project 3/16, ¼ and 5/16 inch square-section continuous rods. Details of the warheads used are given in Table 2.

4.2 For the purpose of the trials the warheads were mounted, some 20 to 30 ft above the ground, on adjustable baseplates secured to a simple tubular structure.

4.3 The slant distance from the centre of the warhead to the mid-chord of the wing interspar region at the station attacked was adjusted, in all the firings, to be 85% of the theoretical maximum hoop radius of the continuous rods. Thus, in the trials the slant ranges for the 3/16, ¼ and 5/16 inch rod warheads were 20, 32 and 25 ft respectively.

5 TARGETS

5.1 The targets used in the trials were full-span Boeing B29 mainplanes, assembled complete with centre fuselage, and mounted in an inverted position, with supports at the wing roots only. Dead weights were placed on the outer wings in eight of the firings to simulate flight stresses at the attack station.

5.2 Details of the method of target mounting and wing loading are given in Appendix 1.

General arrangement drawings of the target layout are shown in Fig.1, and pictorial views of a typical assembly before firing are given in Figs.4 and 5.

5.3 A typical cross-section of the target wing, and diagrams showing the main cross-sectional dimensions of the spar-booms at the stations attacked (Stns.225, 442 and 603), are given in Figs.2 and 3 respectively.

6 INSTRUMENTATION

6.1 In Firings Nos. 1 to 4, the maximum vertical deflections of the target wing tips, occurring as a result of rod strike and blast loading, were measured approximately by means of simple graduated probes mounted in frictional supports above and below each wing tip. After firing, maximum deflections could be read off directly from the probes.

6.2 Blast gauges were set up around the warheads in Firings Nos. 1, 3 and 4, at the positions shown in Fig.1, to measure the blast pressures associated with detonation of the rod warheads. A typical gauge array is shown in Fig.5.

6.3 The mean velocities of the rods between burst point and target were measured by streak photography or deduced from the time taken by the rods to traverse the stand-off distance, measured by a make and break system. Striking velocities were afterwards computed by A.R.D.E. from retardation data, and are given in Table 1A.

6.4 The instrumentation throughout was provided and operated jointly by the staff of D.A.R.D.E. and S.P.E.E.(S).

7 TRIAL PROCEDURE

7.1 Prior to each firing, static wing tip deflections were recorded during a complete loading and unloading cycle of the mainplane. In all cases, other than Firing No.1 (unloaded target), the wings were then reloaded, deflections being again noted. The warhead was then detonated. Maximum wing tip deflections occurring during the firing, and, in cases where the wing did not fail, during the subsequent unloading, were noted. After Firing No.1, a complete loading and unloading cycle was repeated and deflections recorded. From these deflection readings, any permanent set of the wing could be determined.

8 TRIAL RESULTS

8.1 The damage to each of the wing targets resulting from rod attack is detailed in Table 3 and illustrated in Figs.6 to 14.

8.2 Wing tip deflections recorded at the various stages of each firing are given in Table 4, and a record of the blast measurements during Firings Nos. 1, 3 and 4 is given in Table 5. Mean rod velocities measured over the distance from warhead to target are included in Table 1A which also gives approximate striking velocities.

8.3 Cine-still photographs of typical warhead detonations and rod impacts on the target are shown in Fig.15.

9 DISCUSSION OF RESULTS

9.1 The damage resulting from 3/16 inch continuous rod attacks on unloaded and loaded inner wings respectively in Firings Nos. 1 and 2, was broadly similar. In both cases, damage to the spar booms was comparatively minor and thus no significant difference in the effectiveness of the damage could be established. It was noted, however, that detonation of the warhead caused much greater deflection of the unloaded wing relative to the loaded specimen. The smaller deflection of the loaded wing was probably due to the increased target inertia caused by the very heavy masses (7.47 tons) concentrated on the outer wing.

9.2 The results of Firings Nos. 2,3,4,7 and 8 indicated that neither the 3/16 inch, ¼ inch nor 5/16 inch continuous rods, when impacting at velocities of approximately 3300 f.p.s. and at slant ranges equal to 85% of their maximum theoretical hoop radii, was capable of defeating the B29 wing inboard of Stn.225, even from a direction of approach thought to be most favourable to the rods. The 1.5g target loading applied in Firing No.4 (¼ inch rod) appeared to cause no increase in damage effect. In all cases the wing continued to support the load after attack without any significant increase in tip deflection. Figs.6-11, relating to Stn.225, show that most of the lower surface interspar skinning and stringers were severed by all sizes of rod, and, in the attacks by 5/16 inch rods, some damage to the wing upper surface occurred by penetration of broken rods through the full depth of the wing. In every case, however, the heavy lower spar booms were insufficiently damaged to cause wing failure. Thus, the effectiveness of the continuous rod against wings having concentrated load carrying members can be related to its ability to damage these members.

9.3 The B29 mainplane is designed to withstand ultimate manoeuvre accelerations of 4g [4]. Thus, in order to cause failure of the wing in level flight, it may be necessary to reduce the strength of the structure by as much as

75%. In the inner wing lower surface most of the cross-sectional area of the structure, and hence the strength, is in the spar booms and consequently, a reduction in strength of these booms of approximately 75% can result in failure of the wing.

In an attempt to evaluate the reduction in strength of the spar booms after rod attack, the lower spar booms damaged in Firing No.1 were removed from the wing and subjected to tensile tests. These showed that reductions in strength of the front and rear booms were approximately 50% and 25% respectively. These values are well below those required for wing failure. The booms from the remaining five targets will be similarly tested and the results recorded in an Addendum to this Note. It is hoped from these results to obtain a very rough indication of the relative effectiveness of the three types of rod warhead and also of the variation of effectiveness with direction of rod approach.

9.4 The results of Firings Nos.5, 6 and 9 showed that both the 3/16 inch and $\frac{1}{4}$ inch continuous rods, at striking velocities of approximately 3300 f.p.s., were capable of causing complete structural failure of the B29 wing at Stn.442 and outboard, from a typical direction of attack. In this section of the wing the spar lower booms are of relatively small depth and failed in all three firings.

In view of the evident importance of spar-boom depth on rod effectiveness, the approximate depths of the lower booms at some stations along the wing, including those attacked, are given in Table 6.

9.5 From consideration of the B29 wing spar upper boom dimensions, and the results of the firings against the lower surface of the outboard wing, it is estimated that all the warheads tested would be capable of severing the wing upper surface at almost any station along the spar, wing failure being a probable result.

9.6 Measurements taken during Firings Nos. 1, 3 and 4, and reported by A.R.D.E. indicate that the blast effects from the experimental 3/16 and $\frac{1}{4}$ inch rod warheads are approximately the same as those from the detonation of bare charges of 3.4 lb, and 10 lb, of RDX/TNT : 60/40 respectively. Previous trials[5] have shown that charges of this size would produce negligible target damage even at the shortest warhead stand-off distance used in the rod trials i.e. 20 ft.

9.7 The mean rod velocity measured from warhead to target was very similar for all three warheads and lay between 3366 and 3540 f.p.s. The striking velocities were estimated to be between 3216 and 3326 f.p.s.

10 COMPARISON WITH U.S. TRIALS

10.1 No direct comparisons are possible between the U.K. and U.S. firings owing to basic differences in attack conditions and target loading.

10.2 Of the three U.S. firings reported[3], Firings Nos.2 and 3 were normal attacks from above with 3/16 inch warheads against the upper surface of B29 wings at Stn.210, whilst Firing No.1, which was simultaneous with Firing No.2, and on the opposite wing of the same target, was a normal attack from below against Stn.210 of the wing lower surface using a $\frac{1}{4}$ inch rod projector. All three firings resulted in complete failure of the wing.

10.3 The U.S. method of loading the target wings differed from that adopted in the U.K. trials, in that the mainplanes in the U.S. trials were supported near the wing tips in the normal flight altitude, the loads being applied at the inner wings and centre fuselage.

10.4 Neglecting the possible effects of differences in the methods of target loading, it might appear that the U.K. Firing No.8 and the U.S. Firing No.1 would be comparable. However, in the U.S. Firing, the rod projector was located close to the wing surface to be attacked and, as a projector of this type might contain 30 to 40 lb of H.E., some considerable damage from blast would be expected. This, together with possible effects of the simultaneous detonations in the U.S. trial, may account for the fact that the U.S. ¼ inch rod firing resulted in wing failure, whilst the U.K. 5/16 inch rod did not.

10.5 The conditions and results of the U.S. trials are summarized in Table 1B.

11 CONCLUSIONS

11.1 The main conclusions are:-

(a) From the results of a limited number of firings there appears to be no significant difference in the damage obtained from similar attacks with 3/16 inch square-section rods, against B29 wing structures in the unloaded, and "loaded to 1W" condition.

(b) Under the conditions of the trial, neither the 3/16, ¼ nor 5/16 inch continuous rod warheads is capable of defeating the B29 inner wing at Stn.225, when attacking from below.

(c) All three sizes of rod warhead are capable of severing the B29 wing at, and outboard of, Stn.442 from a typical direction of rod approach (45° below and off ahead).

(d) Rod-warhead effectiveness against wings containing concentrated load carrying members appears to be directly related to the ability of the rod to seriously damage these members.

(e) All three sizes of rod warhead are estimated to be capable of severing the B29 wing upper surface at almost any station along the span, wing failure being a probable result.

12 ACKNOWLEDGEMENTS

12.1 Acknowledgements are due to:-

(a) The Superintendent, P. & E.E. (Shoeburyness) and his staff for their co-operation in preparing and carrying out the trials, and for permission to reproduce the illustrations.

(b) The Director, A.R.D.E., and personnel of L5 and X1 Divisions for co-operation in the supply of warheads and the measurement of blast parameters and striking velocities.

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Appendix 1
Tables 1-6
Figs.1-3 SME 83697/R to SME 83699/R
Figs.4-17 Neg. No. 142,675 - 142,689
Detachable abstract cards

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APPENDIX 1

DETAILS OF TARGET LAYOUT AND METHOD OF LOADING

1 The targets used in the trials consisted of full-span B29 mainplanes assembled complete with the centre fuselage. For convenience in attacking the lower wing surfaces and also to simplify the wing loading procedure the whole assembly was mounted in an inverted position, supported by two reinforced concrete pillars, located under each wing root, with shaped wooden cradles under the front and rear spar booms, as shown in Fig.16. The target was restrained in pitch by means of sandbag cradles at the fore and aft ends of the fuselage section, and sandbag cushions positioned below each target wing to restrict secondary damage in the event of wing failure following the rod attack. (See Fig.1).

1.2 In the firings where the target wings were loaded, weights were placed at calculated positions on the outer wings to simulate, at the attack station, the shear forces and bending moments which would normally occur when the aircraft was flying straight and level in non-turbulent air at an all-up weight of 117,000 lb (i.e. with full bomb load and half full load), allowance being made for the contribution to loading due to the weight of the wing itself. In Firing No.4 the applied loads were increased in order to represent, at the attack station, the effect of a $1\frac{1}{2}$g manoeuvre.

1.3 In all cases, the weights to produce the required bending moments and shear forces were supported on wooden platforms, so constructed that the loads were applied through the front and rear spars, (Fig.17).

Details of wing weights, applied loads and points of application together with the resulting forces at the various attack stations are shown diagrammatically in Fig.1 and detailed in Table 1A.

1.4 In the firings where rod attack did not result in wing failure, the damaged spar booms were subsequently strengthened by means of steel straps spanning the wounds, thus enabling the whole target assembly to be used for a further firing against the opposite wing.

TABLE 1(A)

Summary of continuous rod firings against B29 wings (U.K. firings)

Firing No.	Rod size in. x in.	Direction of rod approach	Slant range ft	Rod mean velocity f.p.s.	Estimated rod striking velocity f.p.s.	Target	Attack station	Loading	Result
1	3/16 x 3/16	45° below and off ahead	20	Not recorded	-	Boeing B29 mainplanes inverted and supported at Stn.72	225 lower surface	No load	Wing did not fail
2	3/16 x 3/16	45° below and off ahead	20	3465	3299		225 lower surface	1g flight loads. 7.47 tons (16,640 lb) at Stn.627 giving B.M. = 8,400,000 lb in. S.F. = 24,000 lb at Stn.225	Wing did not fail
3	¼ x ¼	45° below and off ahead	32	3540	3326		225 lower surface	As for Firing 2	Wing did not fail
4	¼ x ¼	45° below and off ahead	32	3500	3296		225 lower surface	1½g flight loads 12.81 tons (28,800 lb) at Stn.627 Giving B.M. = 12,600,000 lb in. S.F. = 36,000 lb at Stn.225	Wing did not fail
7	5/16 x 5/16	45° below and off ahead	25	3395	3263		225 lower surface	As for Firing 2	Wing did not fail
8	5/16 x 5/16	Normal below	25	3366	3234		225 lower surface	As for Firing 2	Wing did not fail
9	3/16 x 3/16	45° below and off ahead	20	3442	3275		442 lower surface	1g flight loads 9.2 tons (20,600 lb) at Stn.634 Giving B.M. = 4,200,000 lb in. S.F. = 23,000 lb at Stn.442	Wing failed
6	¼ x ¼	45° below and off ahead	32	3430	3216		442 lower surface	As for Firing 9	Wing failed
5	3/16 x 3/16	45° below and off ahead	20	Not recorded	-		603 lower surface	1g flight loads 5.85 tons (13,100 lb) at Stn.699 Giving B.M. = 1,300,000 lb in. S.F. = 13,500 lb at Stn.603	Wing failed

TABLE 1(B)

Summary of continuous rod firings against B29 wings (U.S. firings)

(Compiled from Ref.3)

Firing No.	Rod size in. x in.	Direction of rod approach	Rod velocity f.p.s.	Target	Attack station	Loading	Result
1	$\frac{1}{4} \times \frac{1}{4}$ (Rod projector)	Normal below	3300	Boeing B29 mainplanes in normal flying attitude and supported at Stn.533	210 lower surface	1g flight loads Loads applied at centre section Giving B.M. = 8,400,000 lb in. S.F. = 24,000 lb at Stn.210	Wing failed
2	3/16 x 3/16 (Warhead)	Normal above	3800		210 upper surface	As for Firing 1	Wing failed
3	3/16 x 3/16 (Warhead)	Normal above	3800		210 upper surface	As for Firing 1	Wing failed

Notes: 1 Firings 1 and 2 were simultaneous on opposite wings of the same mainplane.
2 Warhead stand-off distances are not known.

TABLE 2

Details of continuous rod warheads used in lethality trials

Firing Nos.	Warhead type	Warhead weight lb	Warhead length in.	Warhead dia. in.	Rod size in. x in.	Rod arrangement	Theoretical max. hoop dia. ft	Liner dia. in.	H.E. filling	H.E. filling wt. lb
1,2,5 & 9	Blue Jay Type IC	48	10.9	8.0	3/16 x 3/16	2-tier	23.5	3.8	RDX/TNT : 60/40	9
3,4 & 6	Red Dean	125	14.8	10.5	$\frac{1}{4} \times \frac{1}{4}$	2-tier	37.3	5.12	RDX/TNT : 60/40	25
7 & 8	Red Dean	140	14.8	10.75	5/16 x 5/16	2-tier	29.7	5.35	RDX/TNT : 60/40	25

All warheads were initiated by means of a centrally positioned No.33 Electric Detonator and a 14 drm C.E. Pellet.

TABLE 3

Record of target damage

Firing No.	Trial conditions	Details of damage
1	3/16 in. rod against Stn.225 of unloaded B29 port wing. (45^o below and off ahead)	Continuous chordwise cut across wing lower surface. All top-hat section stringers (13) severed. Forward spanwise joint stringer 50% severed. Groove in front spar lower boom $\frac{1}{4}$ in. deep and in rear spar lower boom $\frac{1}{8}$ in. deep. Leading edge completely severed. No trailing edge present. Wing remained in position. Figs.6A & B
2	3/16 in. rod against Stn.225 of loaded B29 starboard wing. (45^o below and off ahead)	Continuous chordwise cut across wing lower surface 8 ft 3 in. long. 10 top-hat section stringers severed 3 top-hat section stringers 75% severed. Forward I-beam 50% severed. Cut in rear I-beam 3/16 in. deep. Groove in front spar lower boom $\frac{1}{4}$ in. deep. Groove in rear spar lower boom $\frac{1}{8}$ in. deep. Wing continued to support load. Figs.7A & B
3	$\frac{1}{4}$ in. rod against Stn.225 of loaded B29 starboard wing. (45^o below and off ahead)	Continuous chordwise cut across wing lower surface except for $5\frac{1}{2}$ in. gap on and forward of rear spar boom. 12 stringers and both I-beams severed. Groove in front spar lower boom 11/32 in. deep. Groove in rear spar lower boom 3/16 in. deep. Two holes 4 in. and 1 in. long in front spar web. Holes in undercarriage well outer rib 12 in., $3\frac{1}{2}$ in., $2\frac{1}{2}$ in. long and also two holes 3 in. × 3 in. and 2 in. × 2 in. Wing continued to support load. Fig.8
4	$\frac{1}{4}$ in. rod against Stn.225 of loaded ($1\frac{1}{2}$g) B29 port wing. (45^o below and off ahead)	Continuous chordwise cut across wing lower surface. All stringers and I-beams severed except 1 stringer 50% severed. Groove in front spar lower boom $\frac{3}{8}$ in. deep. Groove in rear spar lower boom $\frac{1}{8}$ in. deep. Six small holes in undercarriage well outer rib. Wing continued to support load. Figs.9A & B
7	5/16 in. rod against Stn.225 of loaded B29 starboard wing. (45^o below and off ahead)	Discontinuous chordwise cut across wing lower surface giving 3 cuts 36 in., 20 in. and 48 in. long. All stringers and I-beams severed except for 2 stringers at the discontinuities. Groove in front spar lower boom $\frac{1}{2}$ in. deep. Groove in rear spar lower boom $\frac{1}{4}$ in. deep. Eight small holes in upper surface interspar skinning. Wing continued to support load. Figs.10A,B,C & D

TABLE 3 (Contd.)

Firing No.	Trial conditions	Details of damage
8	5/16 in. rod against Stn.225 of loaded B29 port wing. (Normal below attack)	Continuous chordwise cut across wing lower surface. All stringers and I-beams severed except 1 stringer 75% severed. Groove in front spar lower boom $\frac{1}{2}$ in. deep. Groove in rear spar lower boom 0.4 in. deep. Numerous rod exit holes and tears in upper surface interspar skinning pulling 17 rows of rivets over 2 ft span. Wing continued to support load. Figs.11A & B
9	3/16 in. rod against Stn.442 of loaded B29 starboard wing (45° below and off ahead)	Continuous chordwise cut across wing lower surface. All structure severed or failed except for part of upper surface interspar skinning. Wing failed completely. Figs.12A & B
6	$\frac{1}{4}$ in. rod against Stn.442 of loaded B29 starboard wing (45° below and off ahead)	Continuous chordwise cut across wing lower surface. All structure severed or failed except for 2 ft length of upper interspar skin. Wing failed completely. Figs.13A,B,C & D
5	3/16 in. rod against Stn.603 of loaded B29 port wing. (45° below and off ahead)	Continuous chordwise cut across wing lower surface. All stringers cut or failed in tension. Wing completely severed. Figs.14A,B,C & D

TABLE 4

Deflection of target wing tips

Firing No.	Loading	Wing	Tip deflection (in.)					
			Before firing		During firing		After firing	
			Unloaded	Loaded	Max downwards	Max upwards	Loaded	Unloaded
1*	7.47 tons at Stn.627	Port (A)	0	+15.13	+9.3	-1.5	+14.75	0
	7.47 tons at Stn.627	Starboard	0	N.R.	+1.6	-1.0	+15.37	+0.25
2	7.47 tons at Stn.627	Port	0	+14.62	+0.5	0	+16.62	+2.0
	7.47 tons at Stn.627	Starboard (A)	0	+16.0	+0.5	-0.75	+19.0	+3.25
3	7.47 tons at Stn.627	Port	0	+15.37	+2.25	-1.25	+17.5	+0.75
	7.47 tons at Stn.627	Starboard (A)	0	+15.5	+0.75	-4.0	+17.12	+0.62
4	12.81 tons at Stn.627	Port (A)	0	+28.62	N.R.	N.R.	+30.24	+1.0
	12.81 tons at Stn.627	Starboard	0	+28.50	N.R.	N.R.	+29.62	+0.25
5	5.85 tons at Stn.699	Port (A)	0	+17.62	Wing failed			
	5.85 tons at Stn.699	Starboard	0	+17.37	N.R.	N.R.	N.R.	N.R.
6	11.02 tons at Stn.543	Port	Tip severed in Firing 5	N.R.	N.R.	N.R.	N.R.	N.R.
	9.2 tons at Stn.634	Starboard (A)	0	+20.62	Wing failed			
7	7.47 tons at Stn.627	Port	0	+15.5	N.R.	N.R.	+15.75	+0.62
	7.47 tons at Stn.627	Starboard (A)	0	+16.0	N.R.	N.R.	+18.12	+1.62
8	7.47 tons at Stn.627	Port (A)	0	+15.75	N.R.	N.R.	+18.75	+1.75
	7.47 tons at Stn.627	Starboard	0	+17.0	N.R.	N.R.	+17.12	+0.75
9	9.2 tons at Stn.634	Port	0	+21.0	N.R.	N.R.	N.R.	N.R.
	9.2 tons at Stn.634	Starboard (A)	0	+21.25	Wing failed			

Notes:
- * This firing was made with wings in the unloaded condition
- (A) Denotes the wing attacked
- \+ Denotes a downward deflection
- \- Denotes an upward deflection
- N.R. Not recorded

TABLE 5

Record of blast measurements

Firing No.	Position	Warhead to gauge distance ft	Peak pressure p.s.i.		Positive impulse lb/m sec/sq in.		Positive duration m secs	Shock transit time m secs
1 (3/16 in. rods)	45° to equatorial plane of warhead	10	22.86		16.41		2.13	3.41
			Incident	Reflected	Incident	Reflected		
	In equatorial plane of warhead	20	5.96*	13.8*	7.9*	18.32*	-	-
3 (¼ in. rods)	45° to equatorial plane of warhead	15.5 20.5 30.5 40.5	20.69 12.59 6.19 4.63		21.98 17.60 12.96 10.79		2.86 3.78 5.47 6.04	5.74 9.05 16.34 24.21
4 (¼ in. rods)	45° to equatorial plane of warhead	15.5 20.5 30.5 41.0	19.31 11.43 5.84 4.56		22.03 17.91 12.95 10.34		3.37 4.21 5.53 6.63	5.71 9.02 16.32 24.47

Note: * These values are estimated

TABLE 6

Approximate depths of lower booms of Boeing B29 wing spars

Wing station (in. from aircraft ℄)		Approximate depth of spar boom (inches) Front spar	Rear spar
100		3.0	2.6
137		2.8	3.0
155	Engine	3.9	3.0
177	nacelle	3.9	3.0
203		3.9	3.0
225		3.9	3.0
236		3.2	3.0
271		2.4	2.1
306		2.3	1.9
341	Engine	2.0	1.7
374	nacelle	1.6	1.5
407		1.1	1.3
442		0.8	1.0
476		0.6	1.8
-	Transport joint		
603		0.7	0.6

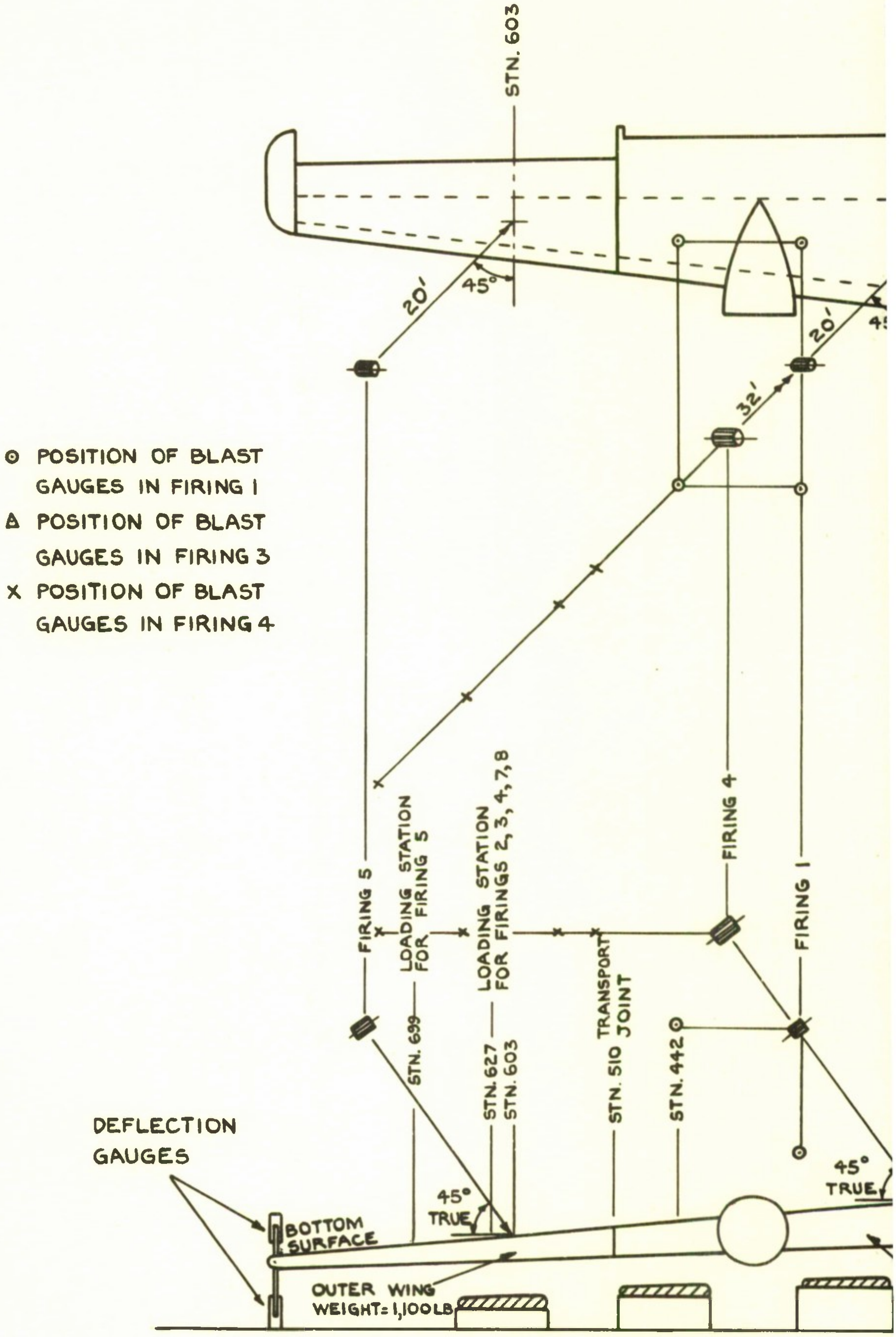
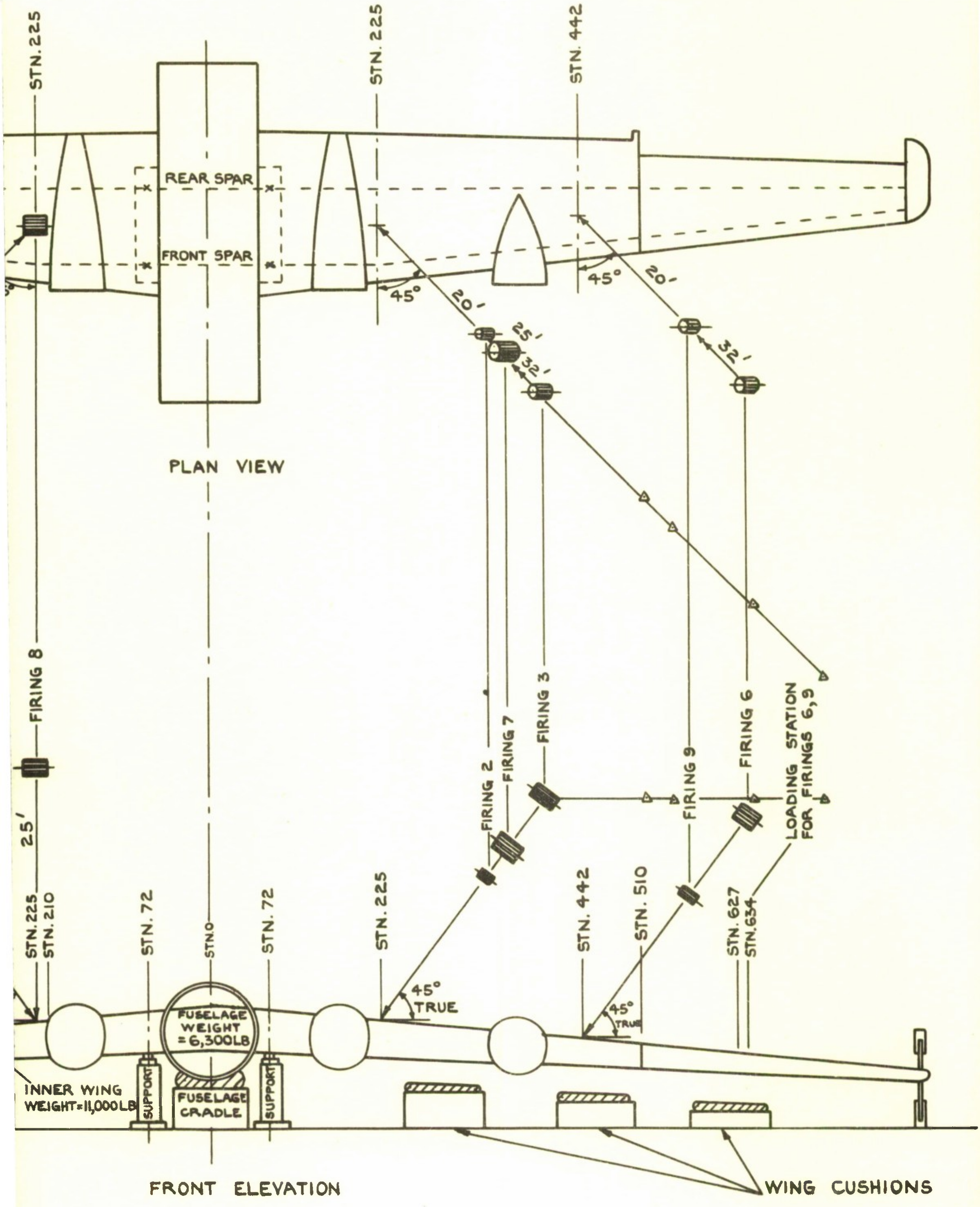


FIG. 1. LAYOUT OF B.29 MAINPLA
WARHEAD FIRINGS.

1

FIG. 1.



NE TARGET FOR CONTINUOUS ROD

SCALE : 1/144

2

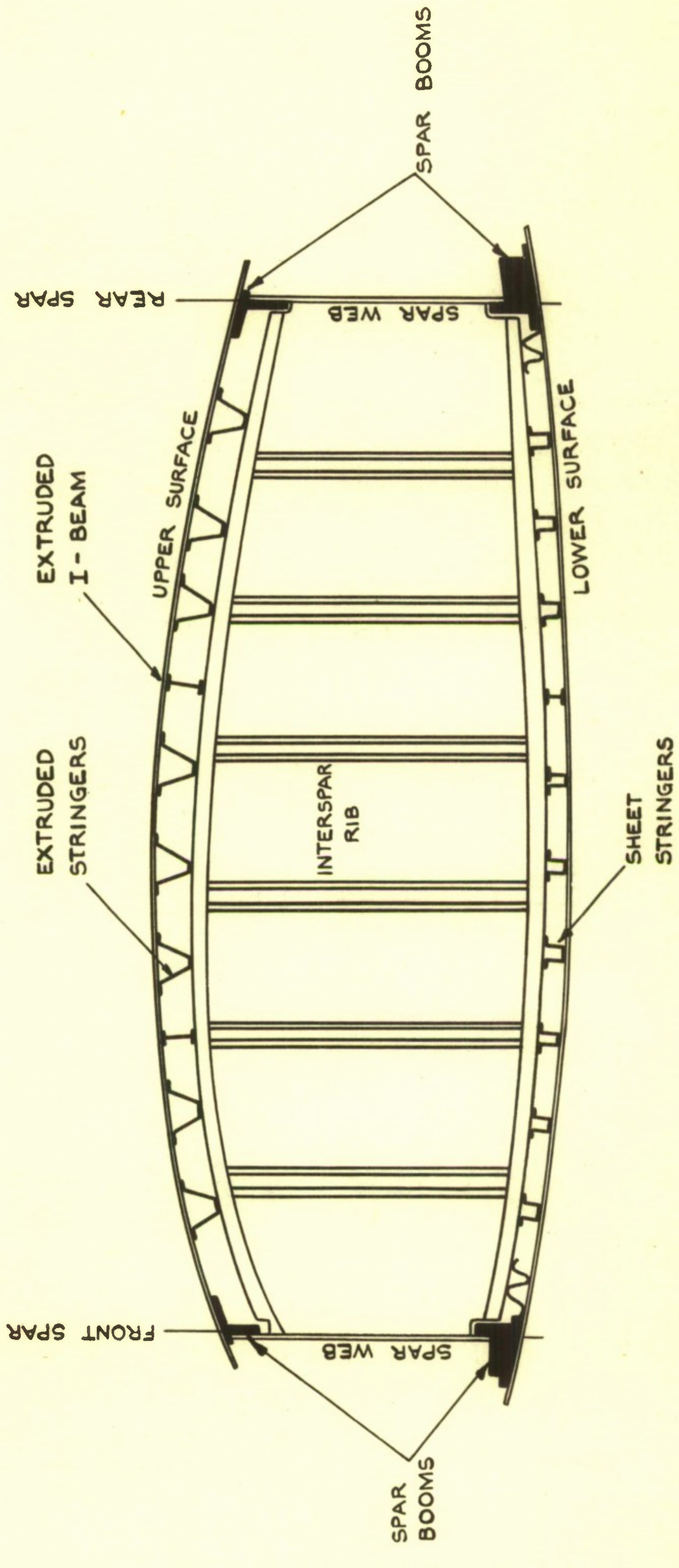


FIG. 2. TYPICAL SECTION OF B.29 WING STRUCTURAL BOX.

FIG. 3 (a-c)

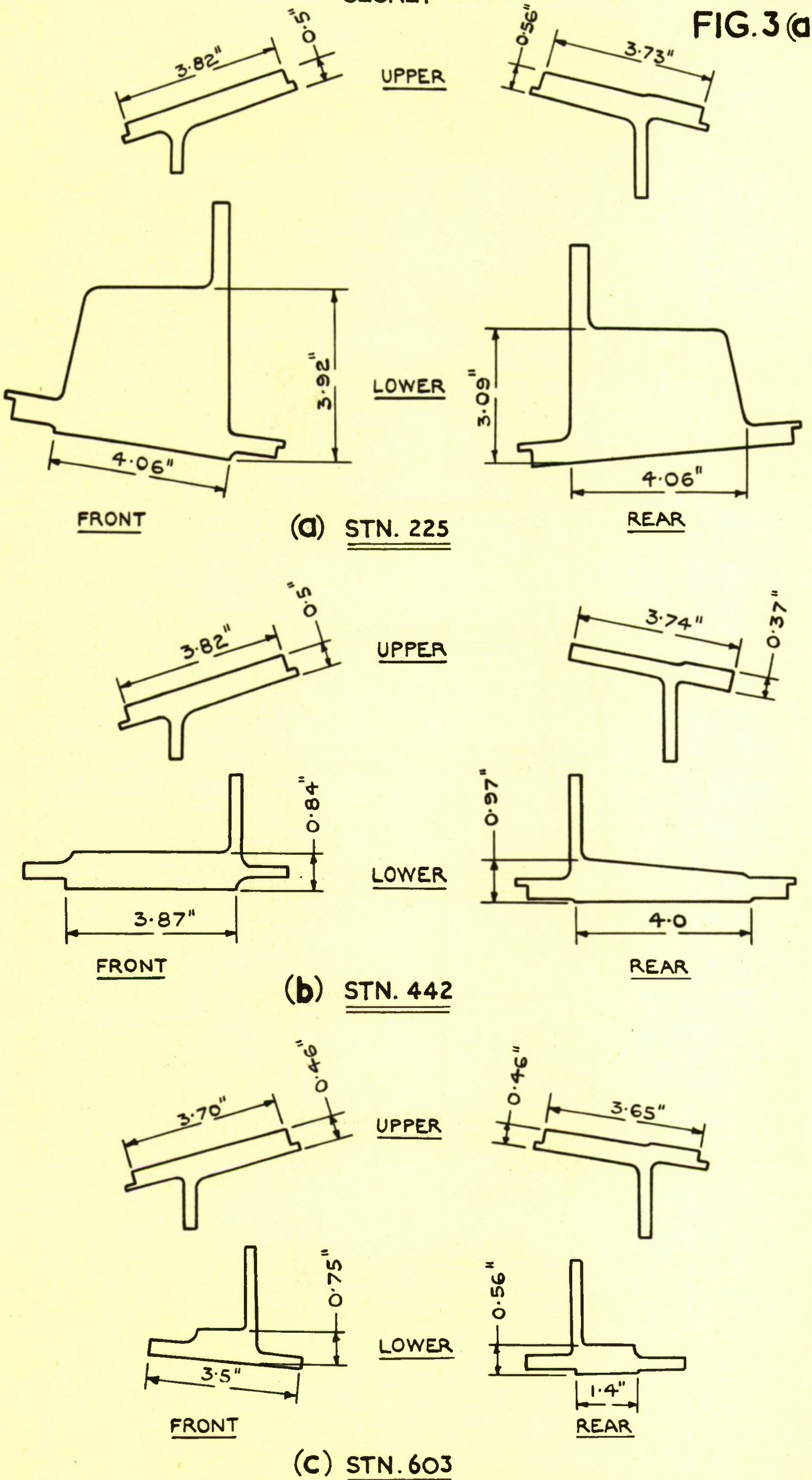


FIG. 3 (a-c). BOEING B29A SPAR BOOM SECTIONS AT ATTACK STATIONS. (SCALE: 1/3)

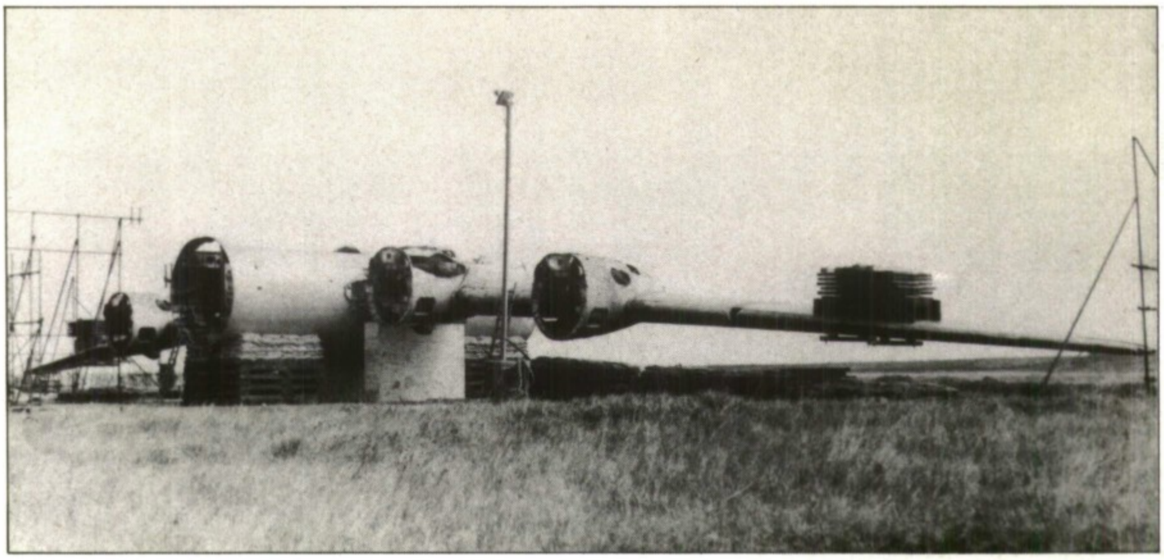


FIG.4. WING SUPPORTS AND FUSELAGE CRADLES (FIRING 2)

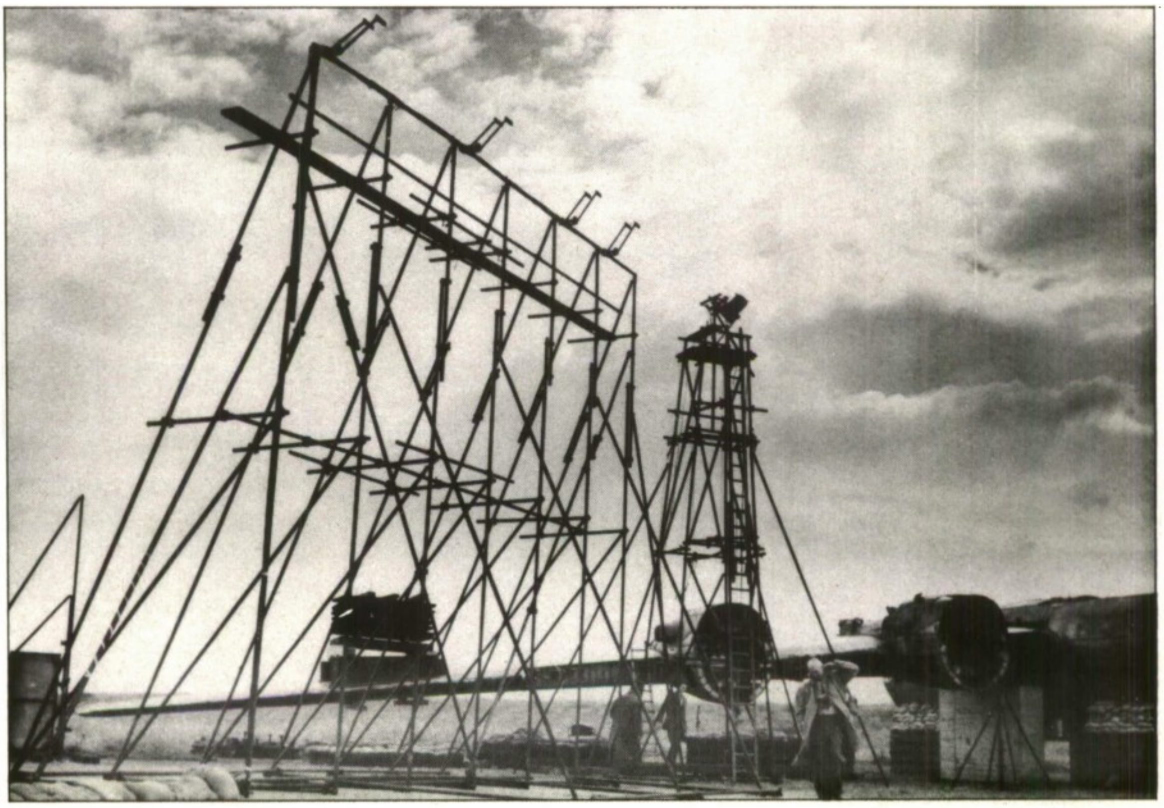


FIG.5. WARHEAD AND BLAST GAUGE ARRAY (FIRING 4)

FIG.4 & 5. TYPICAL TARGET LAYOUT

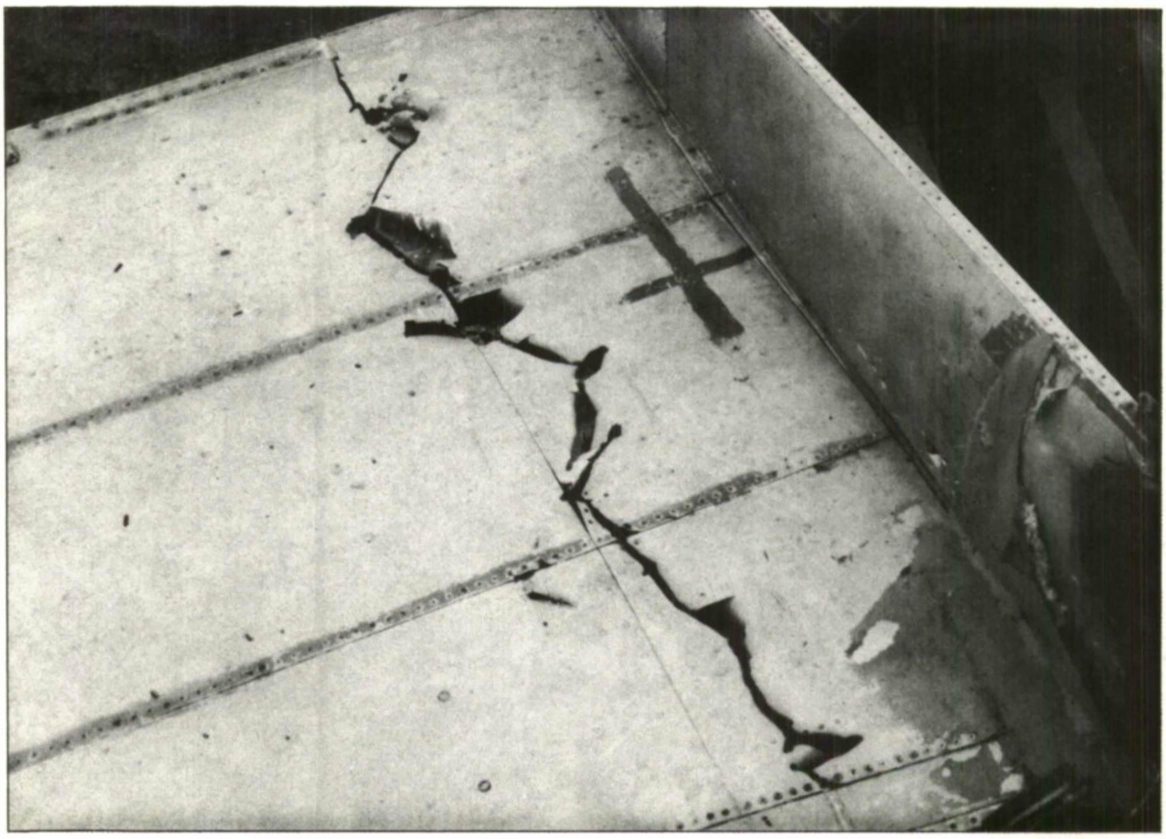
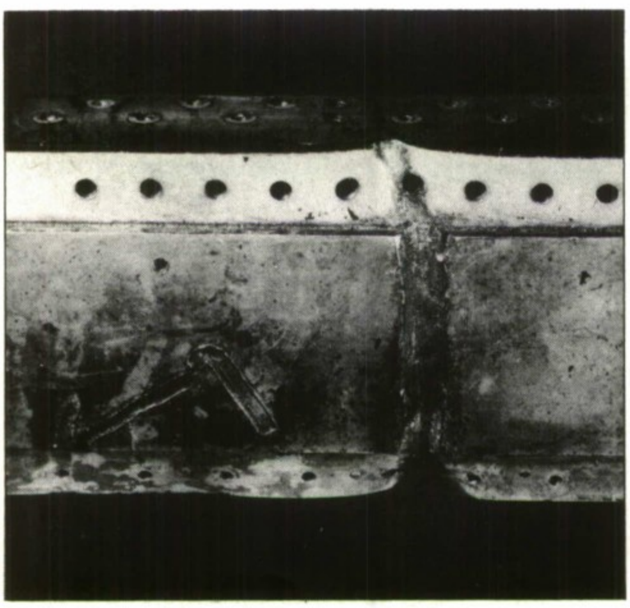
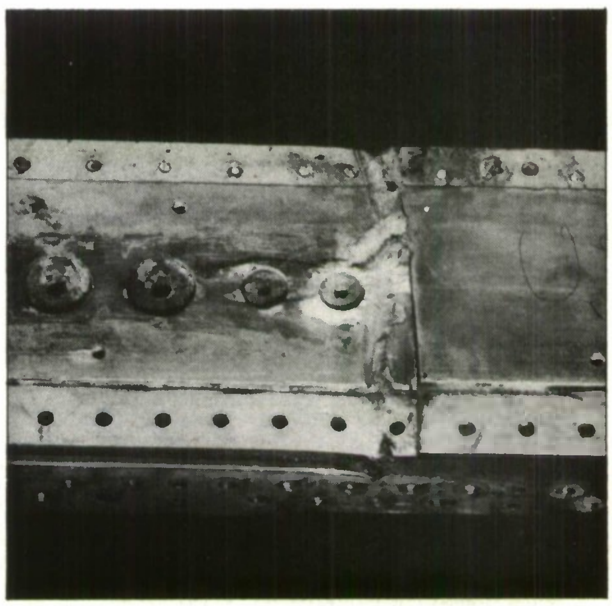


FIG.6a. FIRING I. ROD DAMAGE TO UNLOADED PORT WING (3/16 inch ROD, STATION 225)



FRONT LOWER BOOM



REAR LOWER BOOM

FIG.6b. FIRING I. ROD DAMAGE TO SPAR BOOMS (3/16 inch ROD, STATION 225)

FIG.7

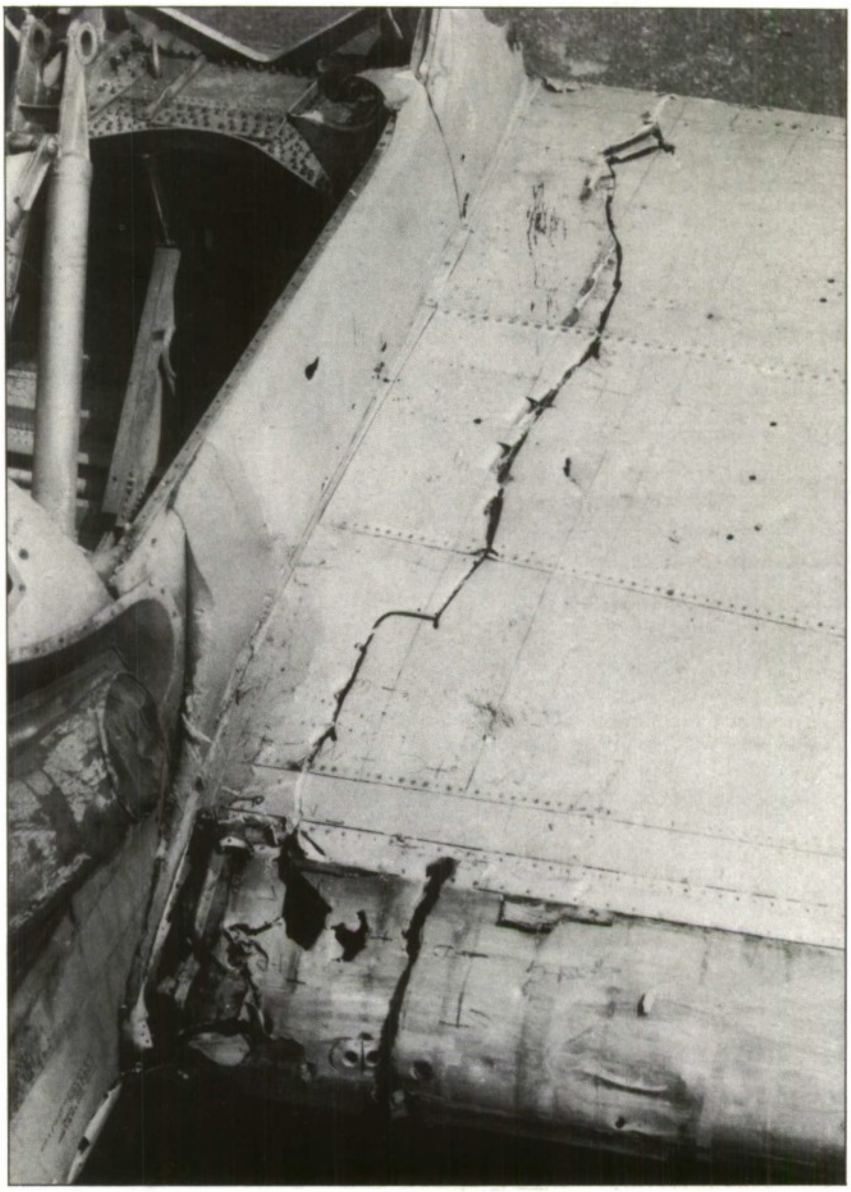
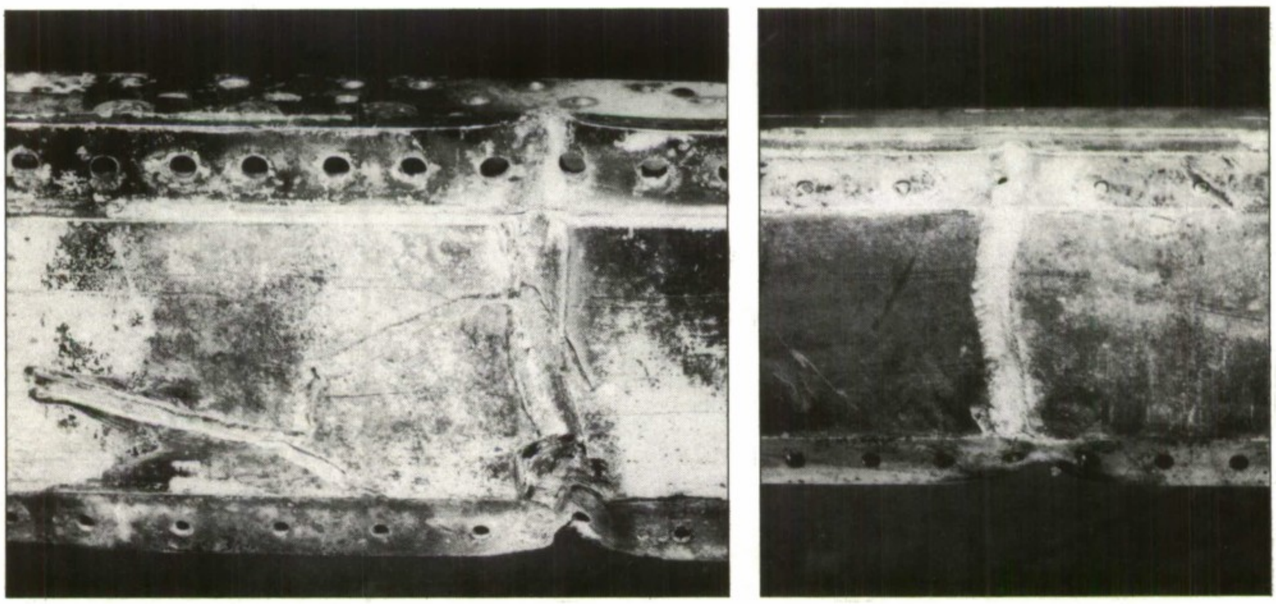


FIG.7a. FIRING 2. ROD DAMAGE TO LOADED STARBOARD WING 3/16 inch ROD, STATION 225)



FRONT LOWER BOOM

REAR LOWER BOOM

FIG.7b. FIRING 2. ROD DAMAGE TO LOADED STARBOARD WING (3/16 inch ROD, STATION 225)

FIG.8. FIRING 3. ROD DAMAGE TO LOADED PORT WING
(1/4 inch ROD, STATION 225)

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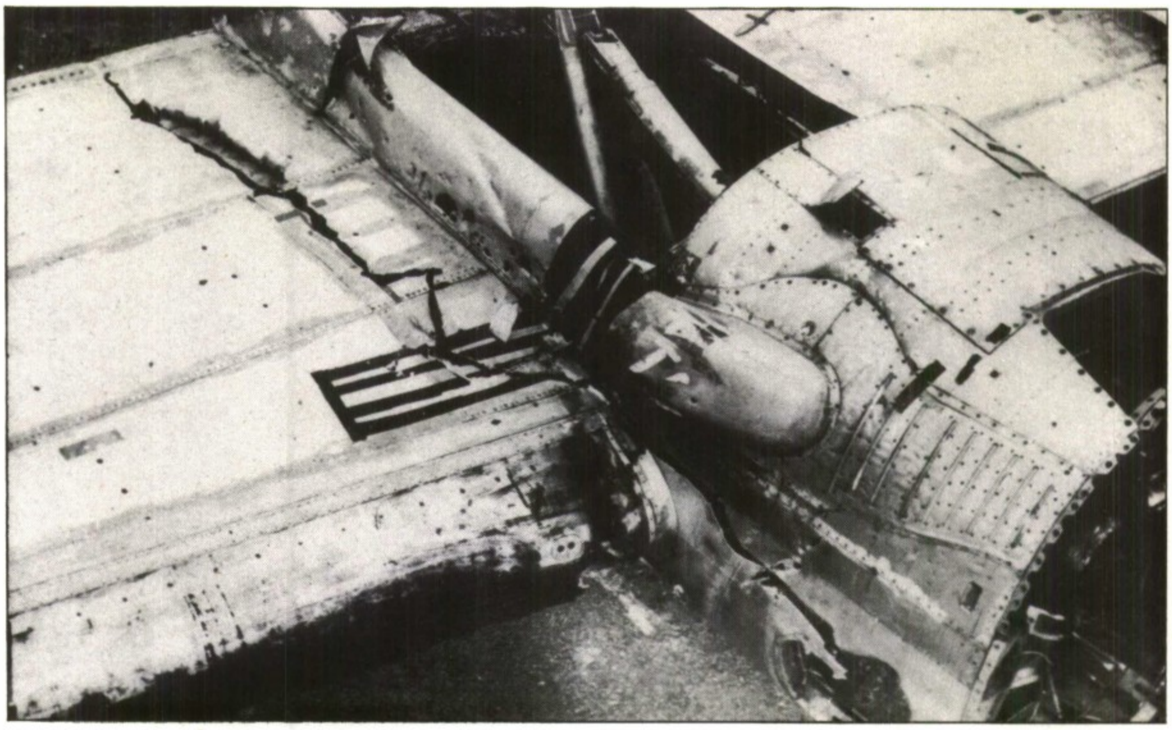

FIG.9a. FIRING 4. ROD DAMAGE TO LOADED PORT WING
(1/4 inch ROD, STATION 225, $1\frac{1}{2}$ g FLIGHT LOADS)

FRONT LOWER BOOM

REAR LOWER BOOM

FIG.9b. FIRING 4. ROD DAMAGE TO SPAR BOOMS
(1/4 inch ROD, STATION 225, $1\frac{1}{2}$ g FLIGHT LOADS)

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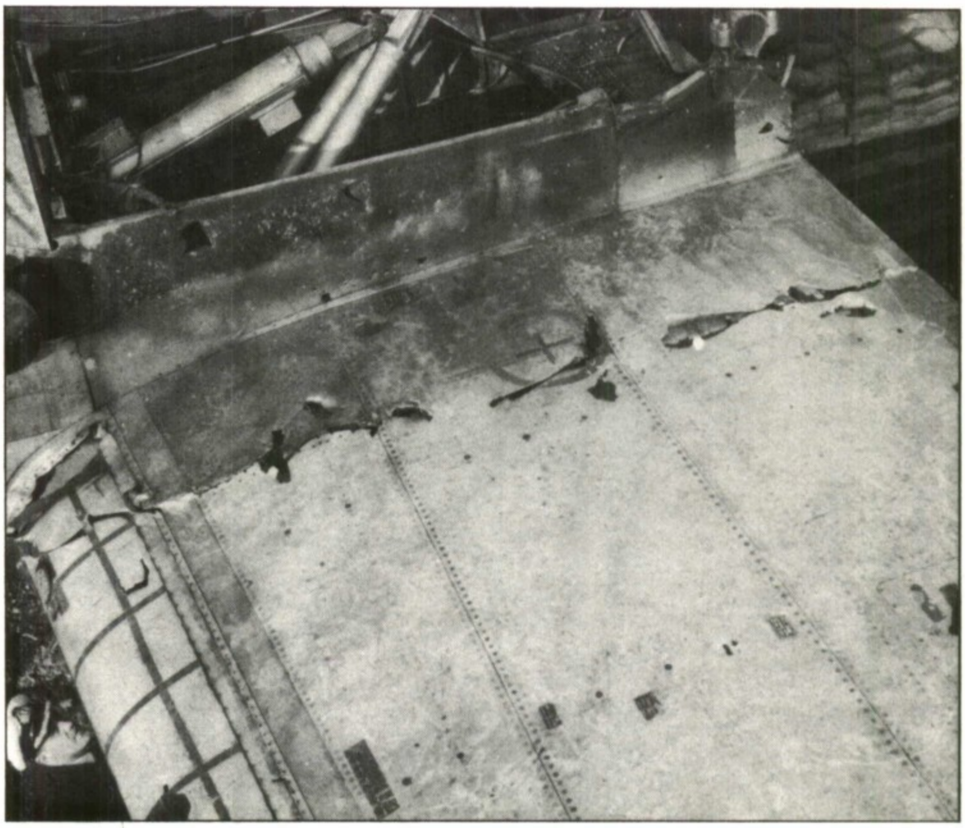

FIG. 10a. FIRING 7. DAMAGE TO LOADED WING LOWER SURFACE SHOWING DISCONTINUOUS CUT (5/16 inch ROD, STATION 225)

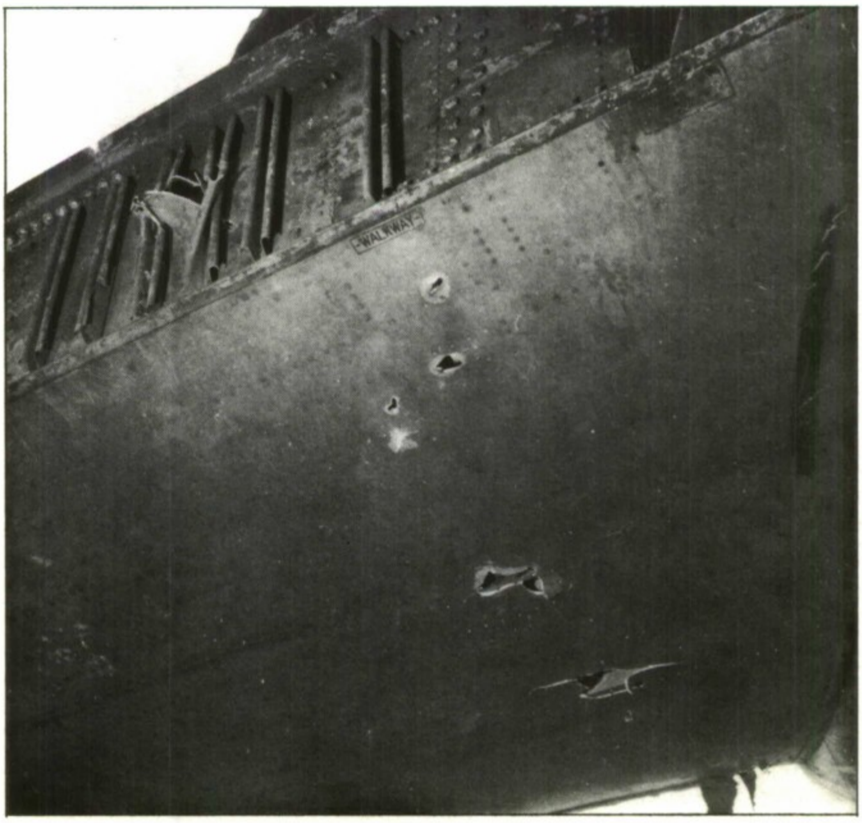

FIG. 10b. FIRING 7. DAMAGE TO WING UPPER SURFACE (5/16 inch ROD, STATION 225)

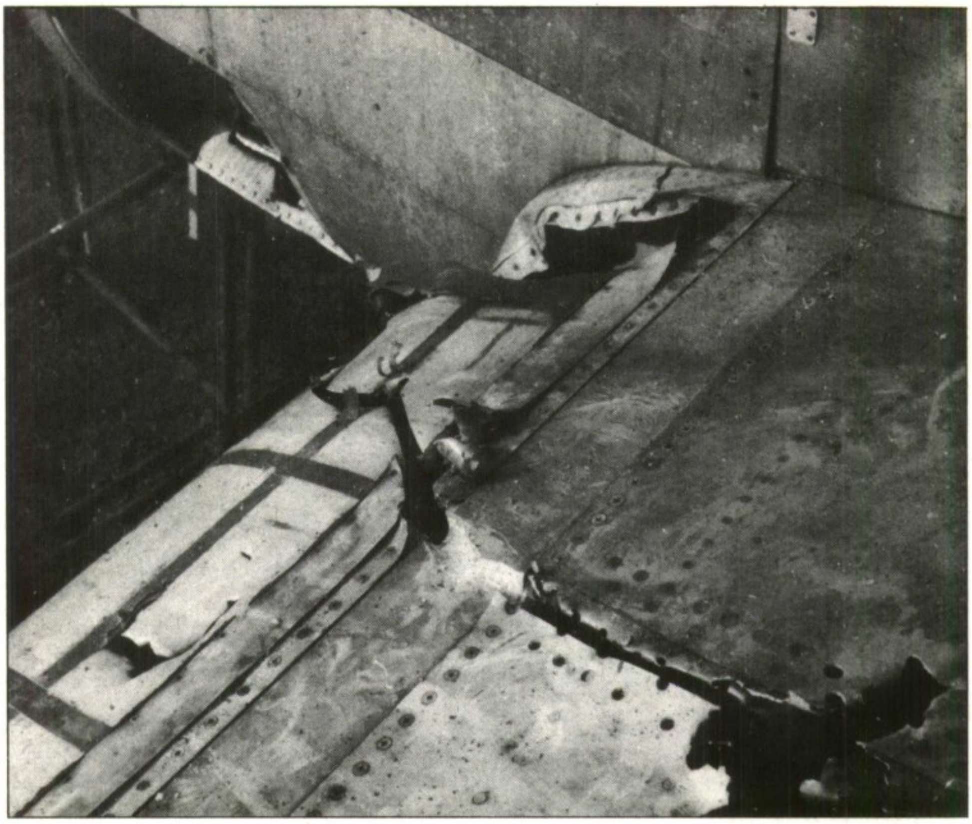

FIG. 10c. FIRING 7. DAMAGE TO FRONT LOWER SPAR BOOM
(5/16 inch ROD, STATION 225)

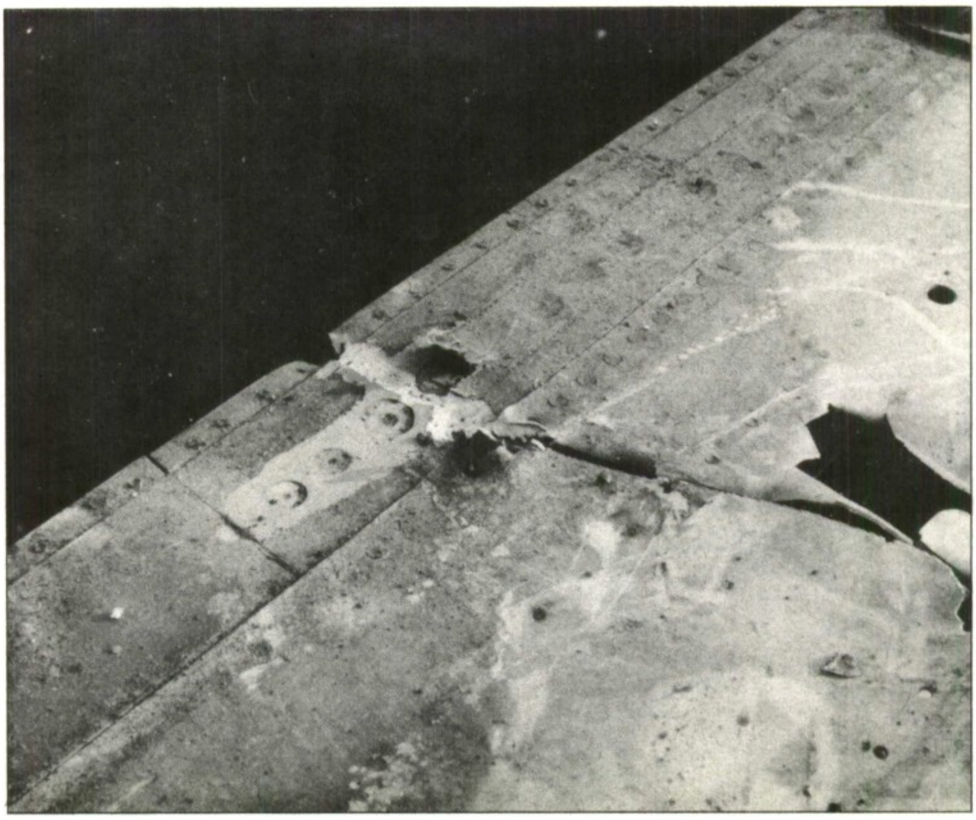

FIG. 10d. FIRING 7. DAMAGE TO REAR LOWER SPAR BOOM
(5/16 inch ROD, STATION 225)

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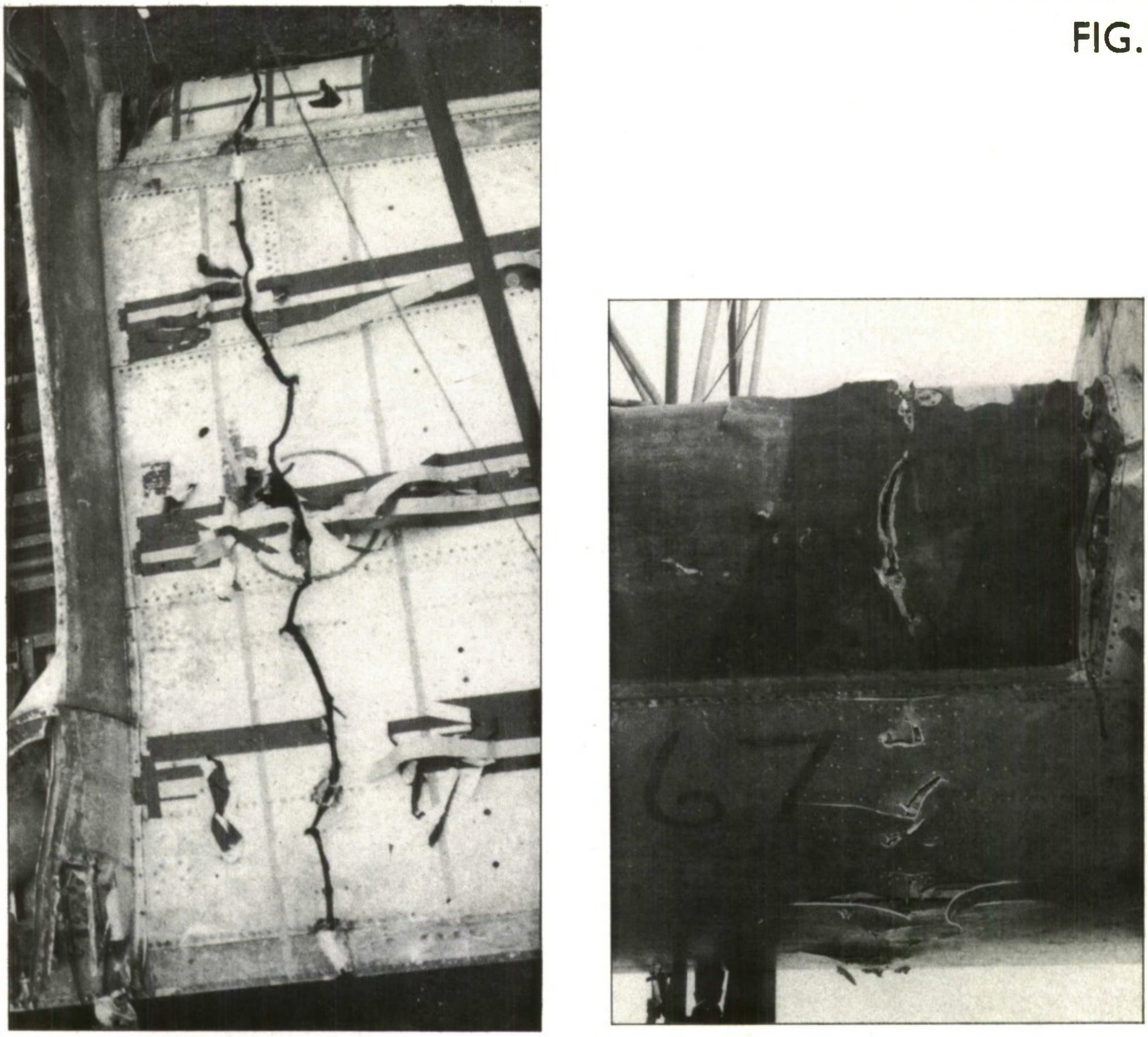
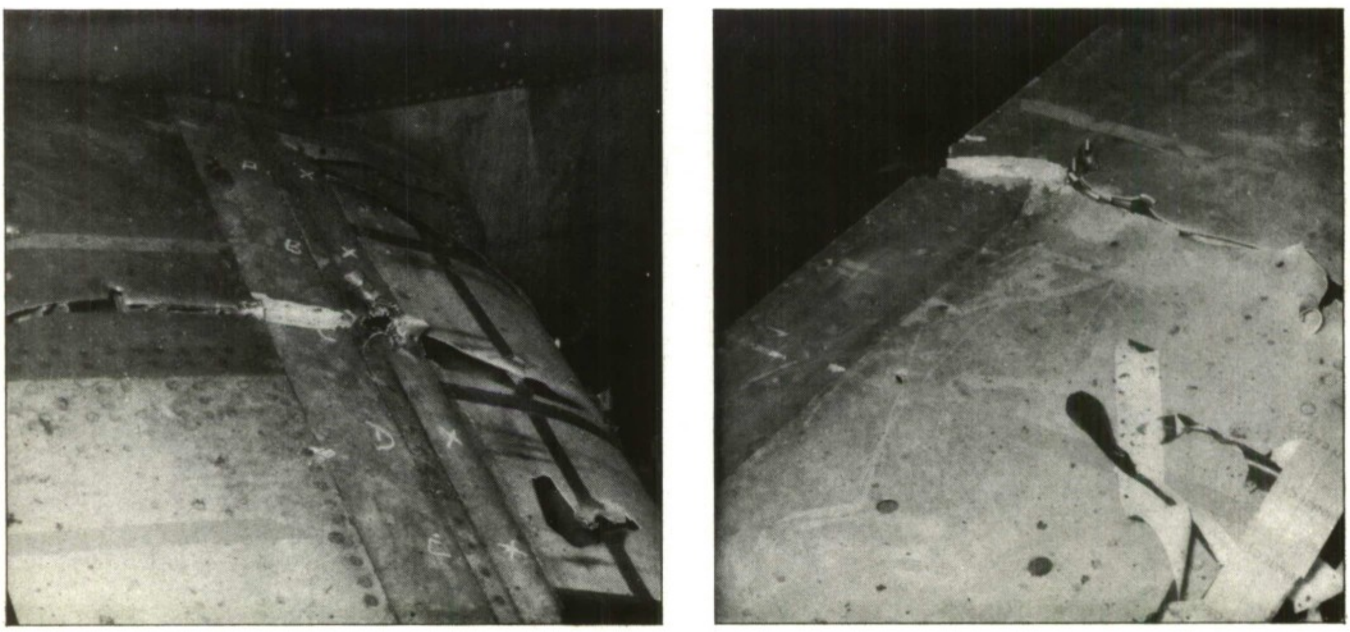
FIG. 11



LOWER SURFACE UPPER SURFACE

FIG. 11a. FIRING 8. DAMAGE TO LOADED PORT WING
(5/16 inch ROD, STATION 225, NORMAL ATTACK)



FRONT LOWER BOOM REAR LOWER BOOM

FIG. 11b. FIRING 8. ROD DAMAGE TO SPAR BOOMS
(5/16 inch ROD, STATION 225, NORMAL ATTACK)

FIG.12

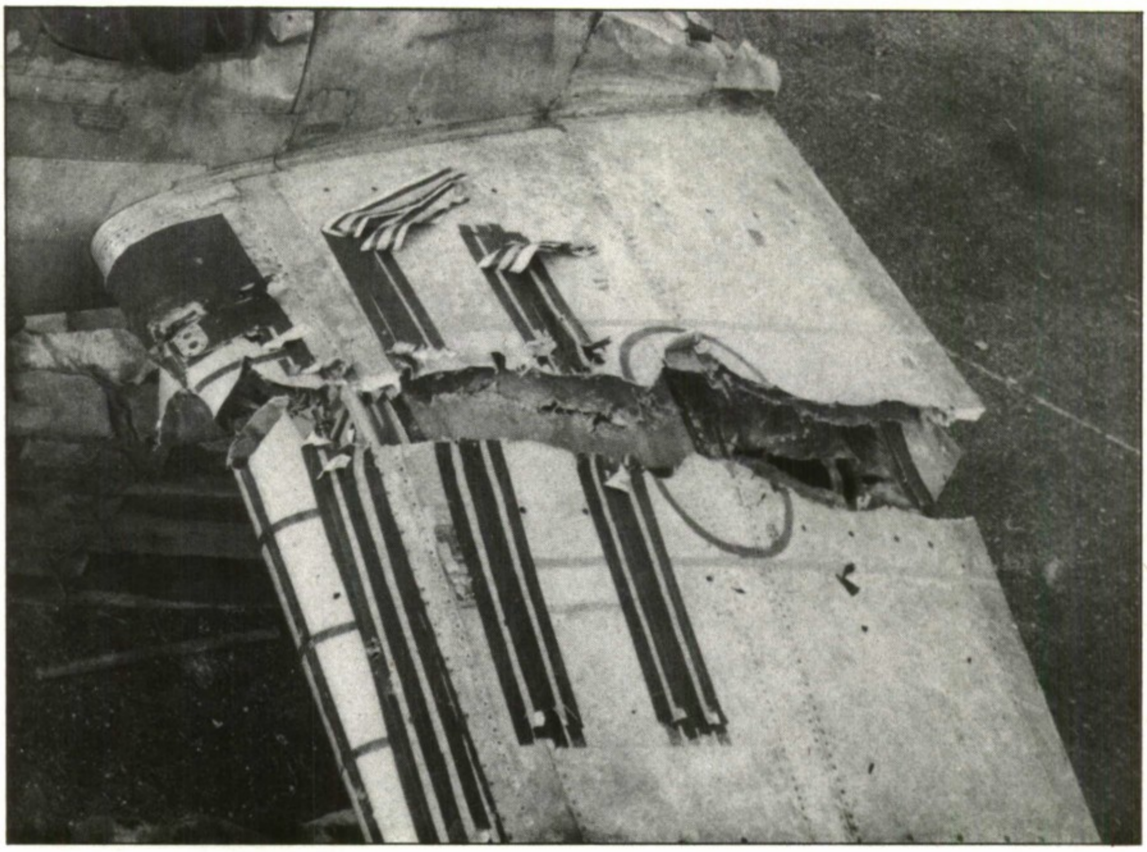
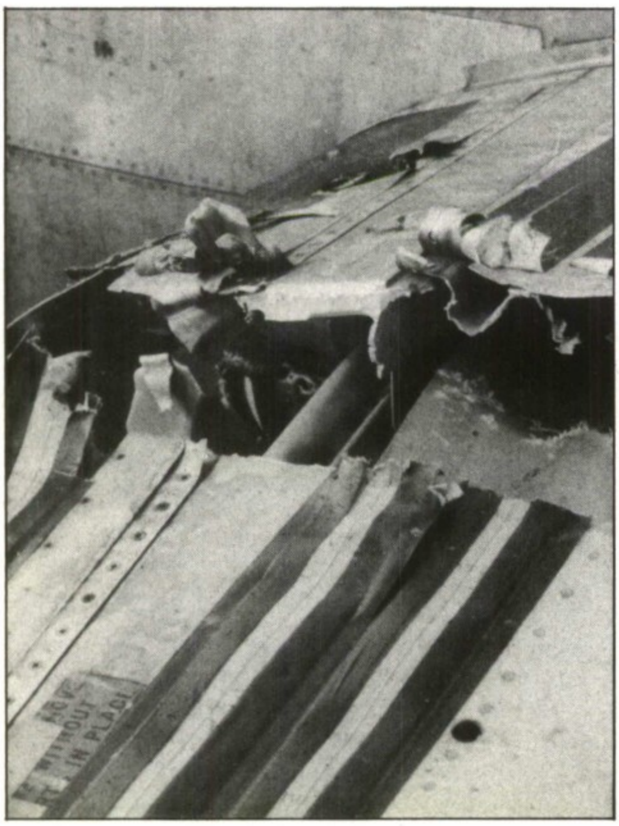
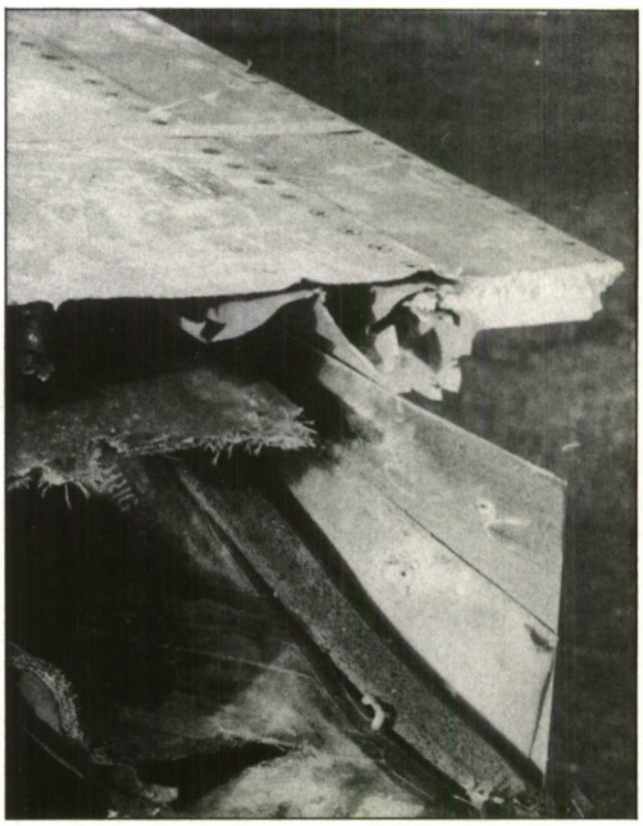


FIG.12a. FIRING 9. ROD DAMAGE TO LOADED STARBOARD WING SHOWING FAILURE (3/16 inch ROD, STATION 442)



FRONT LOWER BOOM



REAR LOWER BOOM

FIG.12b. FIRING 9. SEVERED SPAR BOOMS (3/16 inch ROD, STATION 442)

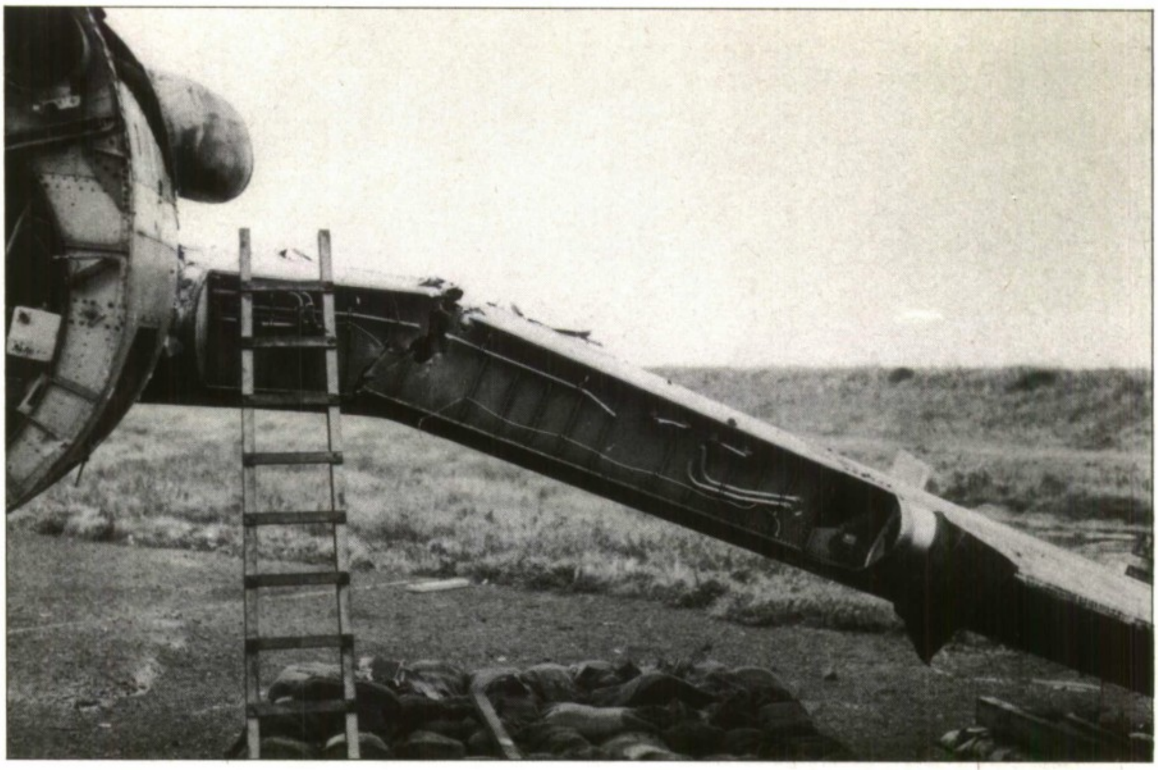
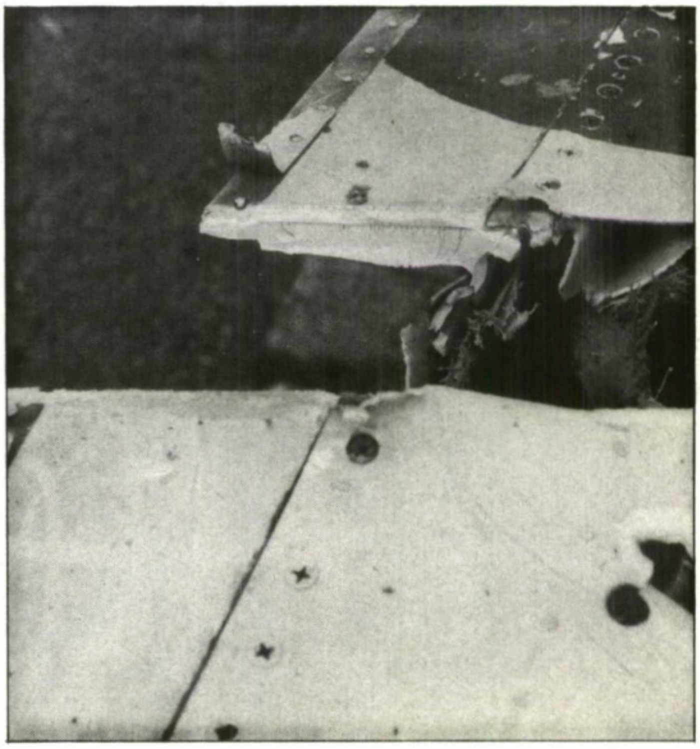


FIG. 13a. FIRING 6. DAMAGE TO LOADED STARBOARD WING SHOWING POINT OF FAILURE (1/4 inch ROD, STATION 442)

FIG. 13b. FIRING 6. DAMAGE TO WING LOWER SURFACE LOOKING INBOARD (1/4 inch ROD, STATION 442)

FIG. 13c. FIRING 6. SEVERED REAR SPAR
(1/4 inch ROD, STATION 442)

FRONT



REAR

FIG 13d. FIRING 6. SEVERED LOWER SPAR BOOMS
(1/4 inch ROD, STATION 442)

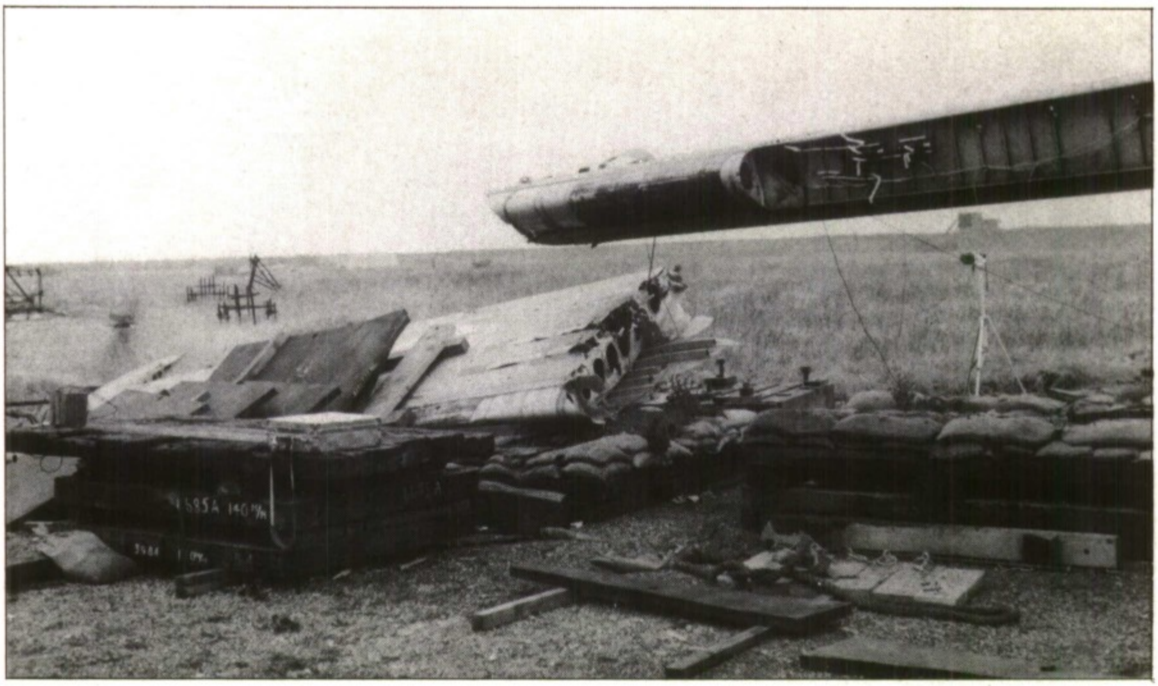


FIG. 14a. FIRING 5. DAMAGE TO LOADED PORT WING SHOWING SEVERED OUTER SECTION (3/16 inch ROD, STATION 603)

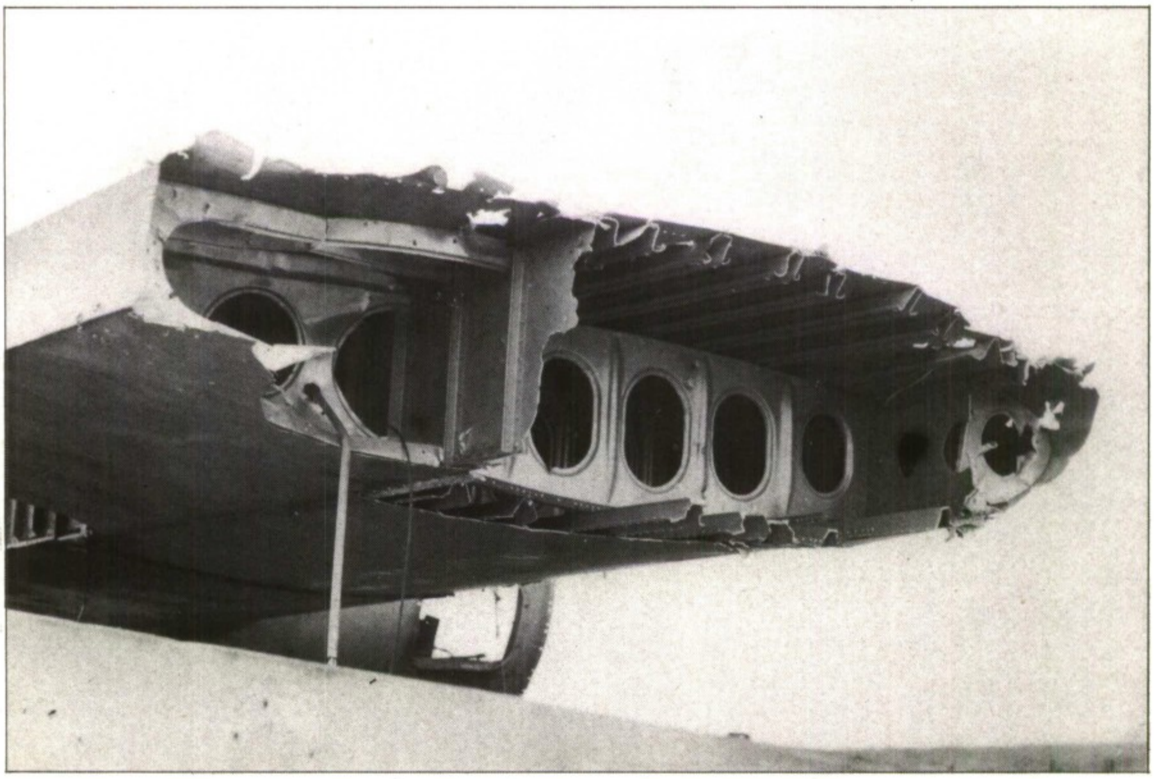


FIG. 14b. FIRING 5. DAMAGED OUTER WING STUB LOOKING INBOARD (3/16 inch ROD, STATION 603)

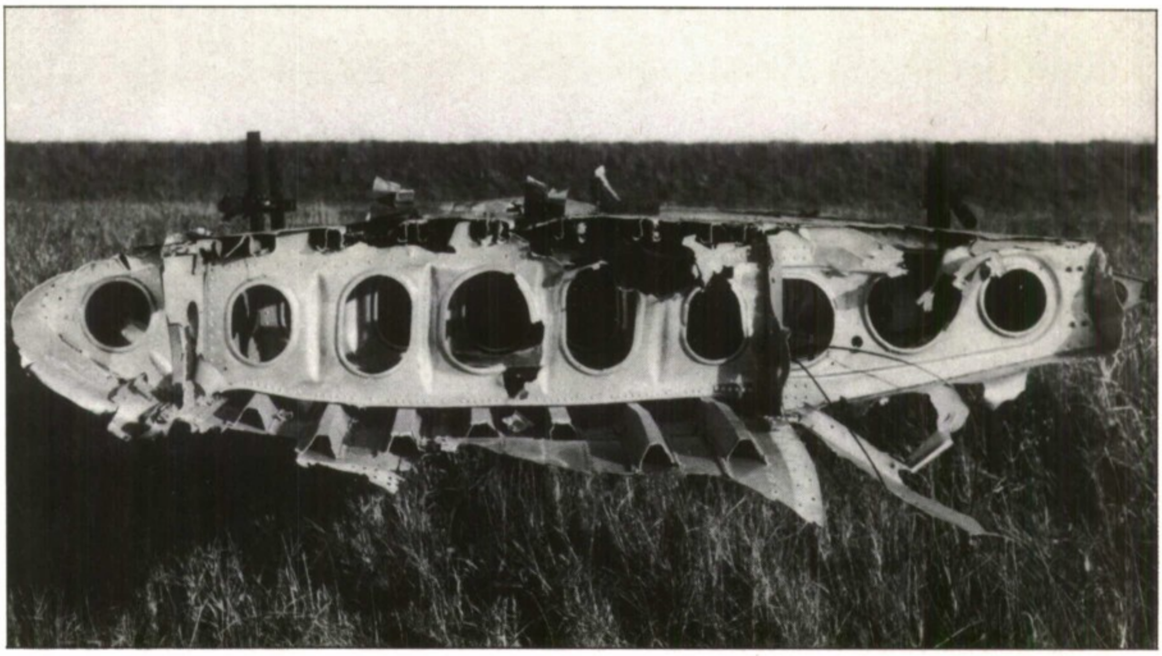
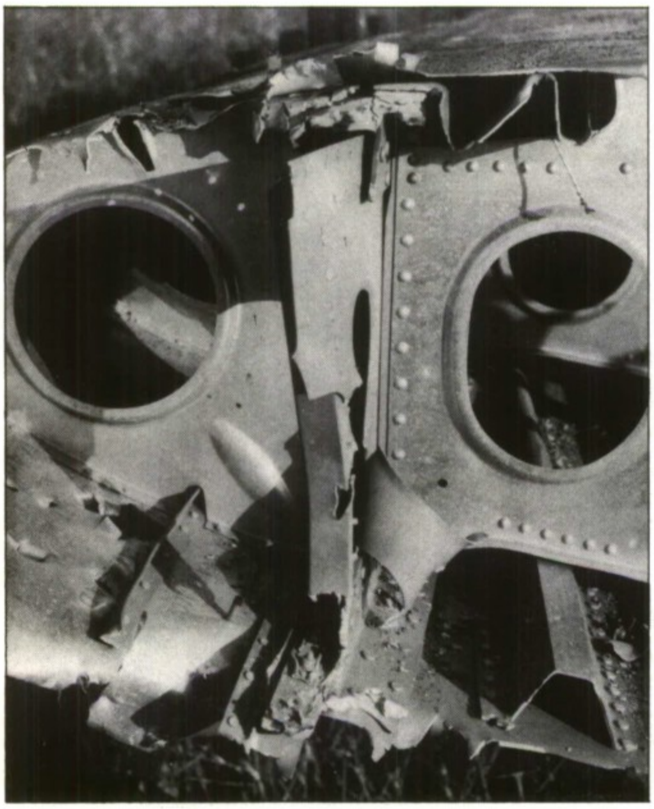
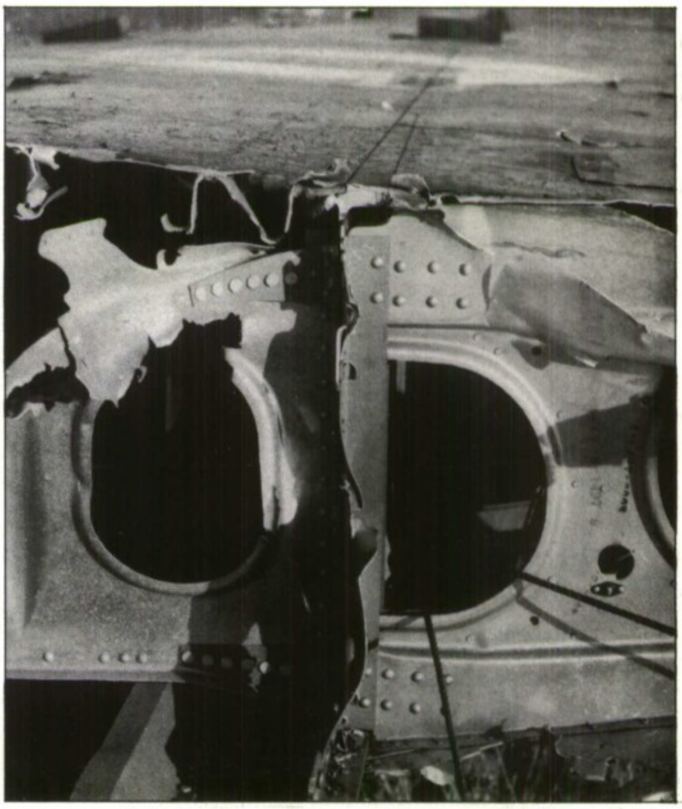


FIG. 14c. FIRING 5. DAMAGE TO SEVERED OUTER WING SECTION (3/16 inch ROD, STATION 603)



FRONT SPAR



REAR SPAR

FIG. 14d. FIRING 5. DAMAGE TO SEVERED SPARS (3/16 inch ROD, STATION 603)

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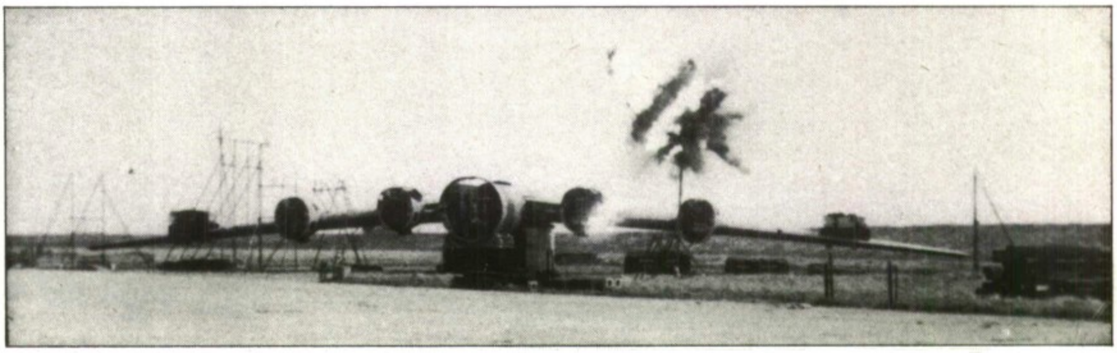

FIG.15a. TYPICAL WARHEAD DETONATION AND ROD STRIKE ON WING (3/16 inch ROD WARHEAD)

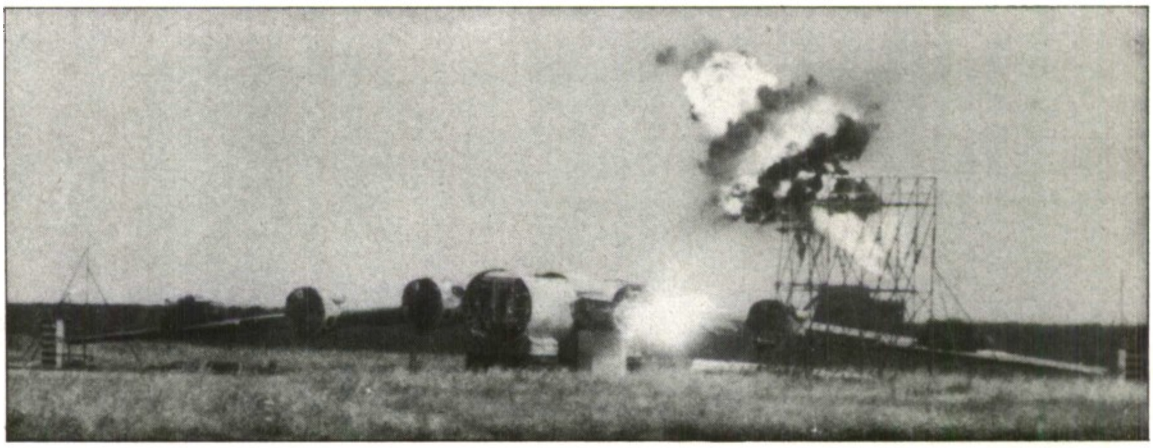

FIG.15b. TYPICAL WARHEAD DETONATION AND ROD STRIKE ON WING (1/4 inch ROD WARHEAD)

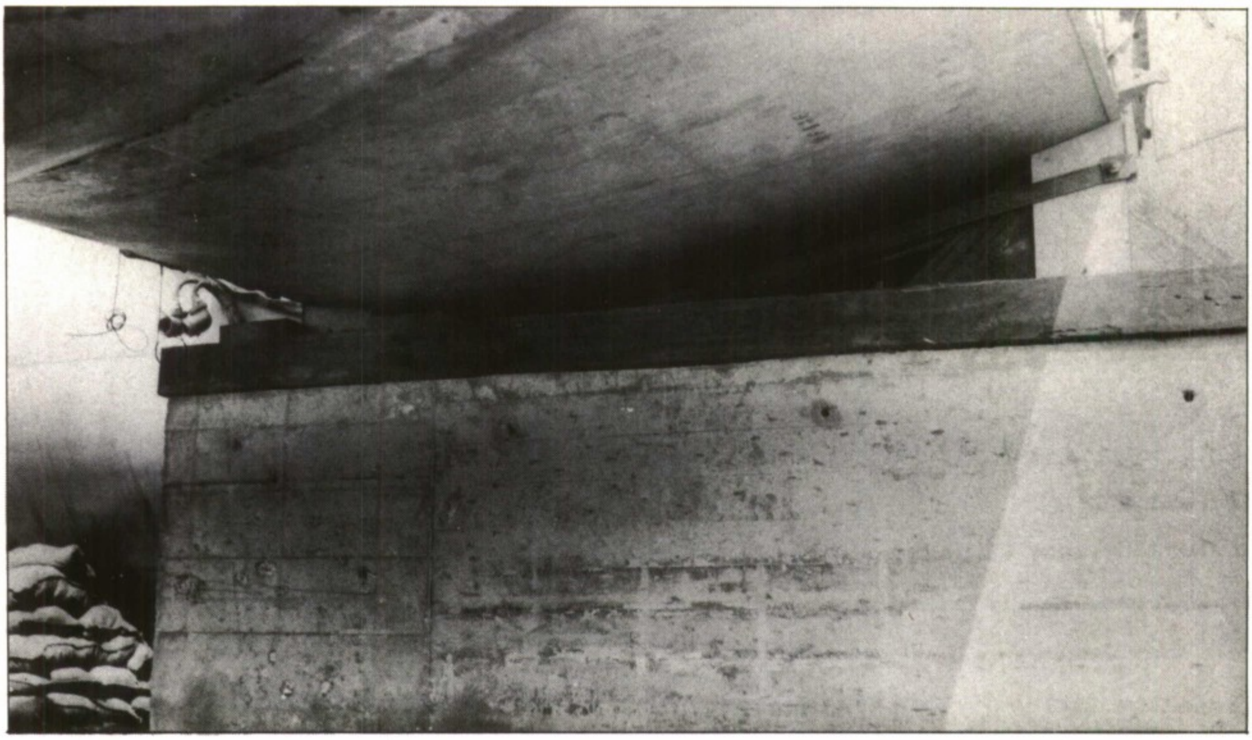

FIG. 16. STARBOARD WING ROOT SHOWING TARGET SUPPORT (PORT WING SIMILAR)

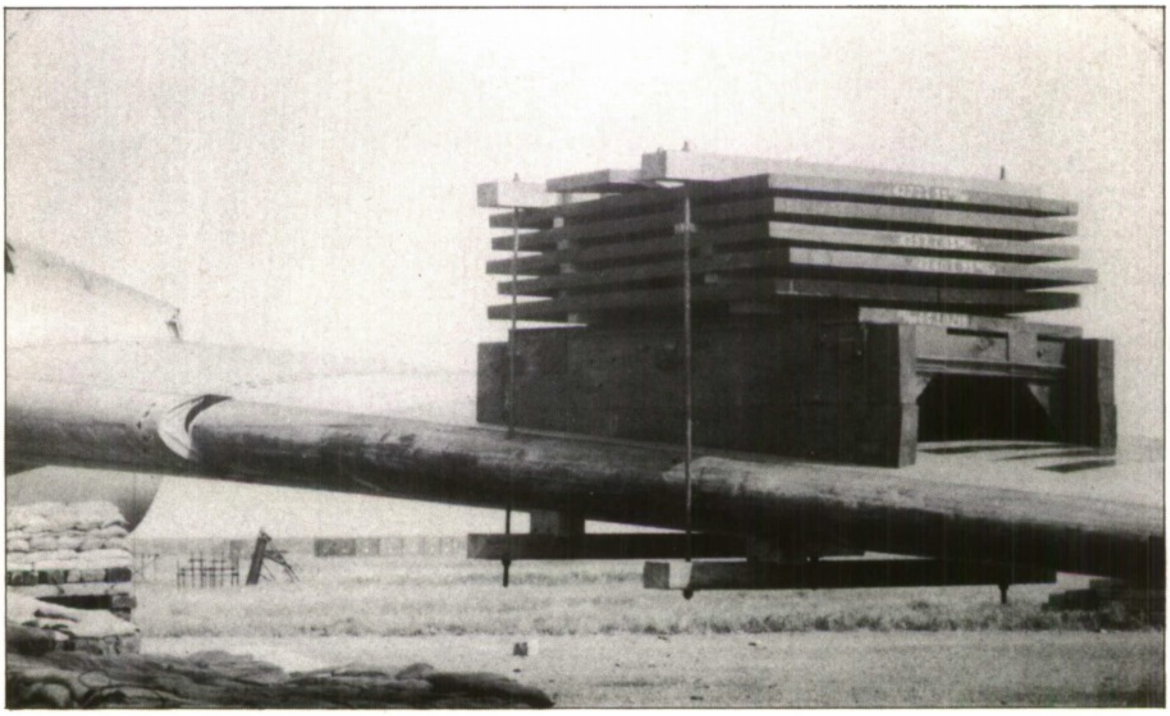

FIG. 17. LOADING ARRANGEMENT ON THE STARBOARD WING (PORT WING SIMILAR)

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623.562.5:
623.746.4

CONTINUOUS ROD WARHEAD LETHALITY TRIALS AGAINST B.29 AIRCRAFT WINGS (3/16, ¼ AND 5/16 INCH SQUARE-SECTION RODS). Mallin, R.G.E. July, 1959.

This Note records the results of nine static detonations of 3/16, ¼ and 5/16 inch square-section continuous rod warheads against Boeing B.29 aircraft wings, eight of which were loaded to simulate flight conditions at the attack station. The results show that when attacking the inboard lower surface of the wing none of the rods is capable of producing structural kills of the target, even from the most favourable directions of rod approach. Against the wing outboard of the engines, however, all three types of warhead are able to cause complete failure of the wing structure, resulting in a Cat. 'K' kill of the target.

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Title: Continuous rod warhead lethality trials against B29 wings (3/16, 1/4 and 5/16 inch square section rods)
Former reference (Department) TECHNICAL NOTE ME 297
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